Volume 18 Number 7

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

JULY 1934

RATTLESNAKE HILLS GAS FIELD, BENTON COUNTY, WASHINGTON[1]

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ABSTRACT

The Rattlesnake Hills gas field, located in eastern Washington, is an unusual occurrence of natural gas at extremely low pressures, but in commercial amounts. It produces a high methane type of gas from 16 wells completed in one or both of two zones of porous basalt flows capped or intercalated with shales. The original well pressure, taken at the casinghead, as nearly as can be determined, was slightly more than 2 pounds, but present field pressures average slightly less. The daily capacity of the wells, as of October 2, 1930, ranged from 25 to 1.5 million cubic feet, and the entire open flow of 10 wells, then constituting the field, was about 5,190,000 cubic feet. Sales of gas in October, 1903, averaged 368,000 cubic feet daily. The field lies on a northeast plunging anticline developed on the north flank of a major northwest-southeast trending belt of anticlinal folding, known as the Rattlesnake range of hills.

INTRODUCTION

The peculiar occurrence of methane gas between basaltic flows in the Rattlesnake Hills field has been the subject of numerous discussions and from these discussions have arisen various theories concerning the origin of the gas and the causes for its accumulation at the particular point of occurrence.

Little has been published on the geology of the area. Shedd,[3] some years ago, prepared a detailed map on the geology of the Pasco and

[1] Manuscript received, September 19, 1932, for the Association's symposium on the natural gas resources of the world—a volume whose scope was subsequently restricted to North America. The manuscript has been revised and the author has given permission for its publication in the *Bulletin*.

[2] Consulting geologist, 2231 Idlewild Street.

[3] Solon Shedd, "Geologic Map of Pasco and Prosser Quadrangles, Washington," *Dept. of Conservation and Development* (Pullman, Washington) *Bull. 32* (1925), Pl. 1.

Prosser quadrangles, but no report was published by him. Culver[4] later published an abstract referring to the work done by Shedd. Both the map and the abstract called attention to the occurrence of gas, but neither report described the structural features of the area.

During October, 1930, the writer examined the local and regional structural features of this area and formed rather definite ideas as to the source of the gas and the conditions under which it accumulates. These ideas and data on the usage and character of the gas are herein set forth.

LOCATION

The Rattlesnake Hills gas field is in Benton County, Washington. It centers around Secs. 20, 21, 28, and 29, T. 11 N., R. 26 E., of the Willamette Principal Meridian. The gas field is about 14 miles northwest of Benton City and 9 miles north and 15 miles east of the town of Prosser.

REGIONAL GEOLOGY

The occurrence of gas under the unusual conditions existing in the Rattlesnake Hills necessitates a broad understanding of the geological history of the region in order to arrive at a fair explanation of the occurrence. The gas field lies near the western edge of a region over which, during part of Eocene time and most of Miocene time, volcanism caused numerous flows of basaltic lava to cover most of the area of the state of Washington, east of the present position of the Cascade Mountains. Geological conditions in this general area during Eocene and Miocene times have been described by Smith.[5] After mentioning conditions at the close of Cretaceous time he states:

> From these older eroded rocks was derived the material for the Eocene sediments, and the process of sedimentation seems to have been a rapid one within this area, since several thousand feet of granitic sands and other sediments were deposited in early Eocene time before uplift again inaugurated erosive activity. Then began the first basaltic eruptions, the forerunners of the great volcanism of the Miocene. This volcanic activity was succeeded by the quieter processes of sedimentation by which the Roslyn sandstone was deposited in middle Eocene time. Somewhat later in an adjoining area deposition of the Manatash sediments took place and the Eocene closed with the uplift and folding of all these Eocene formations.
>
> Erosion continued well into the Miocene within this area, but ceased with the great eruption of basalt, the many flows of which covered the central

[4] Harold E. Culver, abstract of "The Geology and Resources of the Pasco and Prosser Quadrangles" (by Solon Shedd), *ibid.*, *Rept. of Investigations 1* (1926). 5 mimeographed pp.

[5] George Otis Smith, "Geology and Physiography of Central Washington," *U. S. Geol. Survey Prof. Paper 19* (1903), pp. 1–44.

part of the state of Washington like a molten sea. Immediately succeeding this epoch of volcanism came the deposition of the Ellensburg formation, thick deposits of stream sands and gravels brought down from the volcanic area to the west.

The area referred to by Smith is contiguous with, and immediately west of, the Rattlesnake Hills area and the histories of sedimentation in both areas during Eocene and early Miocene time are probably comparable.

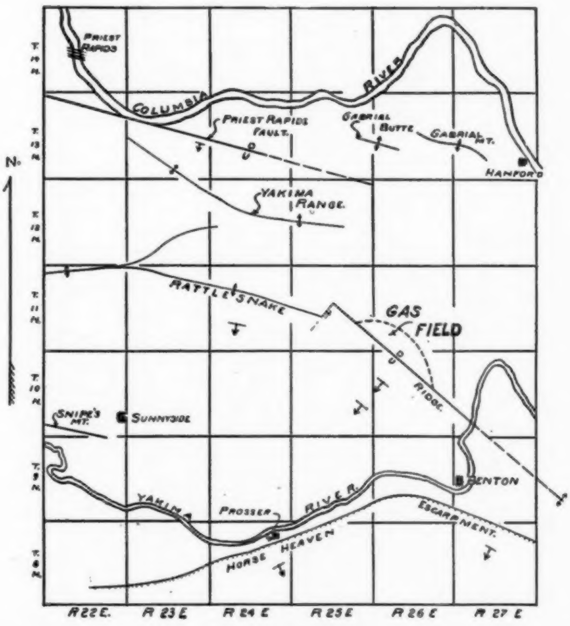

FIG. 1.—Map showing regional structural features in area of Rattlesnake Hills gas field.

STRUCTURAL GEOLOGY

Eastern Washington lies in an extensive physiographic basin. The Bitterroot Mountains in the state of Idaho and the Cascade Mountains of western Washington each have an approximately north-south axial alignment. In the area between these ranges, where definite structural features are known, axes of folds and lines of faulting show an east-west deflection from the north and south alignment of the Cascade Mountains.

The forces which caused the Cascade Range and those that formed the structural features of the Columbia Basin occurred at different times, the former at the close of Eocene time and the latter in late Miocene time, or perhaps continued into post-Miocene time.

There is ample evidence that the structural features of the Columbia Basin, including the Rattlesnake Range, resulted from a south-to-north thrust movement (Fig. 1). The intensity of this thrust was greatest along the Cascade Range and in its vicinity, because in each case the point of the most intense movement occurs on the west along the eastern flank of the Cascade Mountains. And whether the movement was anticlinal in character or consisted of crustal displacement along faulted zones, it gradually becomes less noticeable and finally disappears entirely toward the east. Further, the northward thrust is shown by both anticlines and faults. In every case noted, the thrust caused steeper dips and overturns on the north side of the folds and without exception the downthrown side of faulted areas is on the north.

An outstanding example of the intensity and magnitude of thrust movement, in the general area here discussed, has been found in the locality where Yakima River breaks through the Umptanum Range, just southeast of Ellensburg. Here, on the east side of the highway, occurs a magnificent cross section of an overturned anticline with thrust toward the north, and relatively low dips on the south flank. This range of hills, anticlinal in character, can be traced southeastward until it becomes a part of the Rattlesnake Hills, also anticlinal in character. Other parallel faults and folds occur north of this range (Fig. 1). In order from south to north these are, the Yakima Range anticline with steep north dips, the Priest Rapids fault, Gabrial Butte, and Gabrial Mountains. Gabrial Butte and Gabrial Mountains are faulted anticlines.

Farther north is the Saddle Mountain Range. This range of hills is also anticlinal, as can be easily seen where the range crosses Columbia River southwest of Quincy. Still farther north are the Wenatchee Mountains that closely parallel the previously cited structural features.

In a regional way, therefore, the area extending eastward from the Cascade Mountains to the approximate present position of Columbia River is a continuous series of anticlines, faulted anticlines, and faults, more pronounced on the west but disappearing toward the east and southeast.

At the locality in the Rattlesnake Hills where the gas field has been developed, surface structural conditions are rather easily inter-

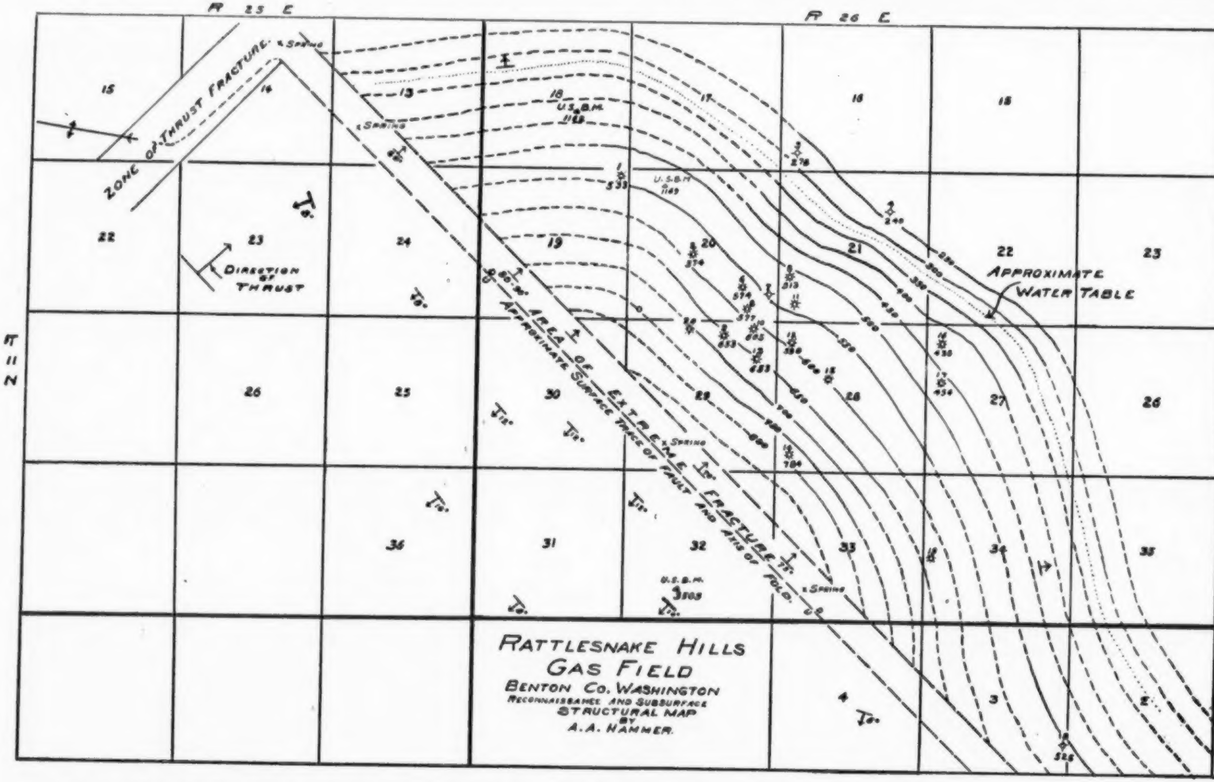

FIG. 2.—Map of subsurface structure, Rattlesnake Hills gas field. Index numbers to wells.

W. W.: Walla Walla Gas Company. N. W.: Northwestern Natural Gas Company. *1*, W. W. No. 3; *2*, Yellowhawk No. 1; *3*, Colfax No. 1; *4*, W.W. No. 4; *5*, W. W. No. 2; *6*, W. W. No. 1; *7*, West Coast No. 1; *8*, W. W. No. 5; *9*, W. W. No. 6; *10*, W. W. No. 7; *11*, W. W. No. 9; *12*, N. W. No. 1; *13* W. W. No. 8; *14*, N. W. No. 2; *15*, N. W. No. 3; *16*, Goodwin No. 1; *17*, Big Bend No. 1; *18*, Hodge No. 1; *19*, W. W. No. 4; *20*, West Coast No. 2.

preted. Here for a distance of about 5 miles the Rattlesnake Hills rise to more than 2,000 feet above the surrounding territory in the form of a major anticlinal fold (Fig. 2). The trace of the fold is N. 45° W. The anticline is faulted, parallel with, and approximately along, its axis. The displacement is thought to be more than 1,500 feet and may reach as much as 2,000 feet at the point of greatest throw.

The northeast side of the fold is a downthrown limb. The drag can be followed for several miles along the surface trace of the fault. Here stratified flows can be seen several hundred feet high, standing at angles ranging from 70° to vertical. Near the northwest end there are some indications of overthrust.

On the southwestern side of the fold the basaltic flows dip at angles ranging from 6° to 12°. These dips continue for several miles southwest, becoming less and less until they are almost horizontal near Yakima River.

In the township west of the one in which the gas occurs, the main axis of the anticline has been offset toward the northeast approximately one mile and the broken condition of the basaltic flows strongly indicates a zone of thrust fracture.

Structural conditions on the northeastern flank of the fold, the downthrown side of the fault, are shown by contours drawn on the top of the principal gas-producing zone (Fig. 2). While there were insufficient wells drilled at the time the mapping was done to show the exact subsurface structure, the conditions are thought to be

TABLE I

Well No.	*Company*	*Location*	*Elevations in Feet Above Sea-Level*		
			Surface	*Top First Gas Showing*	*Top Gas Zone*
1	Walla Walla O. & G.	NW. Cor. NW. SE. Sec. 20	1,279	705	574
2	Walla Walla O. & G.	NW. SW. Sec. 21	1,218	705	513
3	Walla Walla O. & G.	NE. Cor. NE. Sec. 19	1,283	750	533
4	Walla Walla O. & G.	Cen. NE. Sec. 21	958	718	240
5	Walla Walla O. & G.	Cen. SW. SE. Sec. 20	1,332	755	577
6	Walla Walla O. & G.	NW. NE. Sec. 29	1,437	784	653
7	Walla Walla O. & G.	NE. cor. NW. NE. Sec. 29	1,368	763	605
8	Walla Walla O. & G.	C.S.L. NE. NE. Sec. 29	1,437	784	653
9	Walla Walla O. & G.	Cen. SE. SW. Sec. 21	1,228 Drg.		
1	NW. Nat. Gas	Cen. NW. NW. Sec. 28	1,302	712	590
2	NW. Nat. Gas	Cen. SW. SW. Sec. 28	1,705 Drg.		
3	NW. Nat. Gas	Cen. SE. NW. Sec. 28	1,330 Loc.		
1	Yellowhawk	NE. Cor. NE. SW. Sec. 20	1,287	710	577
1	Westcoast	C. NE. SE. SE. Sec. 20	1,265	719	546
1	Big Bend *et al.*	Cen. SW. NW. Sec. 27	1,124	670	454
1	Goodwin *et al.*	Cen. NW. NW. Sec. 27	1,134	699	435
1	Colfax	Cen. SW. SW. Sec. 16	1,018	740	278
1	Hodge well	NE. Cor. SE. SE. Sec. 3			

essentially as here indicated. In addition to subsurface data the observed surface dips support the structural form here shown.

Data on which the subsurface mapping was done are given in Table I.

A study of the logs and cores of Walla Walla Well No. 7 (Sec. 29, T. 11, R. 26) and the Seattle Oil and Gas Company's Goodwin *et al.* No. 1 shows that the gas occurs in a porous phase of basalt at the top of a flow and that the porous gas-bearing phase is overlain by 60–70 feet of green and gray clays. These clays appear to be decomposed and redeposited basalt, being derived largely from the olivene and pyroxene minerals of the original basalt. Careful examination of these clays shows nothing present that could act as a probable source of gas.

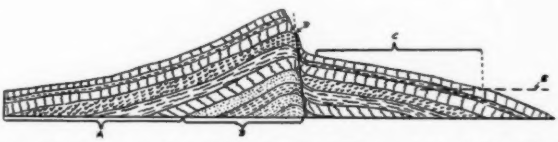

FIG. 3.—Ideal cross section of Rattlesnake Hills gas field. *A*, basaltic flows. *B*, probable Eocene and early Miocene sediments. Likely source of gas in this area. *C*, position of present productive area. *D*, point of gas escape along fracture zones. *E*, approximate position of water table in principal producing horizon.

The writer has prepared a generalized cross section (Fig. 3) of the fold indicating the probable underground conditions and a likely source of the gas.

THICKNESS OF FLOWS

In the area northwest of the Rattlesnake Hills more than 4,000 feet of basalt has been measured. The total thickness beneath the Rattlesnake Hills is not known. However, a well near Yakima was still in basalt at a depth of more than 2,500 feet when visited by the writer in 1930. Since the depths of basaltic flows depend on the number and thickness of flows, together with the character of the terrain at the time of flow, the maximum thickness of the flows can not be determined until a well has definitely been drilled into older rocks.[6]

SOURCE ROCKS

Smith's description of sedimentation during Eocene and presumably during early Miocene time indicates that there was probably not sufficient carbonaceous material originally present or preserved

[6] A deep well is being drilled with rotary tools in the field. In December, 1933, this well was at a depth of 1,595 feet, drilling in basalt. (Edit.)

to act as a source of considerable amounts of methane gas unless it be the Roslyn coal measures.

The Roslyn coal measures are known to be approximately 3,000 feet thick. They consist of massive sandstones with clays and bony shales, the Roslyn coal seams, and less valuable beds of coal in the upper part of the measures that are associated with dark-to-black shales.

The Ellensburg formation, according to Smith, consists largely of coarse gravel and sand of volcanic origin in the area of his studies. Farther east, where exposed, the Ellensburg formation consists largely of fine volcanic ash with bentonite and some true shales in small amounts. Diatoms have been observed sparingly in some localities associated with the shales and volcanic ash. Personal examination by the writer has shown only scattering particles of vegetable matter, such as twigs and small limbs of trees.

Elsewhere in eastern Washington around the edges of basaltic flows, nothing has been observed beneath the basalt that suggests a probable source of gas. In the vicinity of Wenatchee and toward the north and northeast, basaltic flows overlap old metamorphic rocks. Near Spokane, basalt rests on granites, gneisses, schists, metamorphosed shales, and limestones. Approximately 40 miles south of Spokane, Steptoe Butte, consisting almost entirely of quartzite, rises several hundred feet above the surrounding eroded basaltic prairie. Between Almota Ferry on Snake River and Lewistown, Idaho, erosion has cut through the basalt, exposing a granite peak in contact with basaltic flows.

Thus, it is seen that the basalt east of the Cascade Mountains in Washington flowed over various formations. As far as known, none of the overlapped formations offers a probable source for gas, with the possible exception of the Roslyn coal series or other rocks of similar character and age, or possibly unknown buried rocks of early Miocene age. The best example known to the writer, proving that considerable time elapsed between flows, can be seen about 30 miles south of the town of Asotin, along Grande Ronde River, in the southeastern part of the state. Here Grande Ronde River has cut through several hundred feet of basalt. Near the top of the canyon and for several miles along the rim is a deposit of charred wood, which has been mined at times and used for fuel. At this locality vegetable matter in the form of leaves, twigs, limbs of trees, and pieces of logs as much as 2 feet in diameter accumulated. This material is found partly buried in a stratified bed of white-to-yellow clay between basaltic flows. Elsewhere, throughout the many canyons that have been cut

into the basaltic flows, there are only isolated known occurrences of vegetable material between basaltic flows. In the known localities only scattered pieces of wood and charred branches of trees have been found. Certainly these scattered particles of vegetable matter nowhere seem adequate to act as a source of gas in quantity.

HISTORY OF DEVELOPMENT

Gas was discovered in 1913, while a well was being drilled for water. The discovery well, known as Walla Walla No. 1, was drilled to a depth of 1,000 feet. Two gas-bearing zones were reported at depths of 705–715 feet and 827–915 feet. This well flowed open intermittently for several years and on several occasions the gas was ignited and burned for months at a time.

Several wells were drilled between 1913 and 1929. The existence of the gas which these wells demonstrated was used at various times to promote further ventures, none of which was successful. It was not until 1929 that the right to develop the area and utilize gas from the field was acquired by people experienced in the natural-gas business. The new operators prepared a program which has led to the development of a commercial supply. By October, 1930, 15 wells had been completed, of which 9 were gas wells and 6 were dry holes. More wells have been drilled since that time, and there are now 16 gas wells.

In 1929 a 6-inch line, 23 miles long, was laid from the gas field to Grandview, and 4-inch branch lines were laid to Prosser, Sunnyside, Mabton, Grandview, Zilla, Grangen, and Toppenish, a total of 48 miles.

Between December, 1929, and October, 1930, meter connections increased from 52 to 404 and total monthly sales increased from 770,000 cubic feet to 11,408,000 cubic feet. The total value of gas sold during this period amounted to more than $28,000.00. Recent information shows that up to the present time (December 15, 1933), approximately $240,000.00 of gas (value at consumer's meter) has been sold from the field.

CHARACTER OF GAS

The gas consists mostly of methane, as is shown in Table II.

OPEN-FLOW CAPACITY

Open-flow capacity of wells, in thousand cubic feet, on October 2, 1930, as given by J. Mann, is shown in Table III.

TABLE II

	Percentage
Helium	0.00
Carbon dioxide	0.15
Oxygen	0.15
Methane	97.25
Ethane	0.00
Nitrogen	2.45
	100.00

TABLE III

	Thousand Cubic Feet
Walla Walla No. 1	25
Walla Walla No. 2	1,500
Walla Walla No. 5	300
Walla Walla No. 6	300
Walla Walla No. 7	250
Walla Walla No. 8	260
Goodwin No. 1	85
Big Bend No. 1	70
Yellowhawk No. 1	1,200
Northwestern No. 1	1,200
Total open flow	5,190

GAS PRESSURES

Various estimates of pressures have been given at different times since the discovery of the field, but the first known authentic tests were made by R. B. Newbern[7] in 1929. The results are shown in Table IV.

TABLE IV

Date of Test	Inches of Mercury	Remarks
Aug. 5, 1929	3.4	All wells shut in
Sept. 8, 1929	3.1	All wells except one shut in
Feb. 17, 1930	3.0	All wells except one shut in
Mar. 7, 1930	2.7	
Sept. 19, 1930	1.6	3 wells shut in
Sept. 26, 1930	1.8	Northwestern Nat. No. 1 shut in
Sept. 30, 1930	1.8	Yellowhawk No. 1 shut in
Oct. 27, 1930	1.6	Northwestern No. 1 shut in

Of the manner and conditions under which these pressures were taken Newbern states:

Test made on August 5, 1929, of 3.4 inches of mercury was with the entire field shut in. On September 8, 1929, and February 17, 1930, all wells were shut in except one which was being used for drilling purposes. On September 19, 1930, only three wells were shut in and we had begun to use two compressors. On September 26, and September 30, and October 27, 1930, the pressure was taken by shutting in only one well and the station being operated at the same time.

[7] President, Northwestern Natural Gas Company.

Fisher[8] calls attention to the pressure tests made by Newbern and to earlier investigation of pressures. Concerning pressures he states:

> One of the larger wells, Walla Walla No. 2, was open to the air for many years, wasting probably in excess of a billion feet of gas, and the records and statements of men familiar with the history of these wells show no differences of pressure excepting those attributable to the crudeness of the pressure gauge used in the early tests.
>
> During the tests of the field made by Mr. Newbern, all of the wells were left open for four months and pressures taken very carefully. The normal pressure of approximately 24 ounces appeared immediately upon shutting the wells in at the end of this test. The quantity blown to the air on the basis of open flow tests, and the time flowing, was in excess of 270 million cubic feet.

The writer believes that the low field pressures represent the frictional resistance to gas escape along the faulted anticline, that the gas is not indigenous to the strata in which it occurs, and that its source lies in deeper rocks of Eocene or early Miocene age, buried beneath the principal basaltic flows. Gas escaping upward along the fracture zones associated with the fault collects in part in various porous zones between basaltic flows, and in part is continuously dissipated to the atmosphere through these fractures. Migration has probably been more or less continuous since the time of folding.

Seasonal changes of pressure, observed through a long period of years, suggest that the low reservoir pressure is due to frictional resistance of the escaping gas. Invariably at times of heavy rainfall or melting snow on the Rattlesnake Hills, the closed-in pressure of the wells has been observed to increase. An explanation of this phenomenon is the added friction due to water and silt which at those times enter the fractures along the fault zone. Conversely during seasons of drouth the well-head pressures invariably decline to their lowest stages.

Further, the water table on the down-dip side below the gas-producing area and in the producing horizon shows a low hydrostatic head. In the Colfax well in Section 16 the producing horizon contained water, which rose in the hole and maintained a head of 60 feet, equivalent to a pressure of 26.04 pounds. This leads to the justified assumption that the actual water table is approximately 60 feet structurally higher than the Colfax well and is apparently close to a constant level, since no water has been found in other wells structurally higher and no water has entered other wells displacing gas withdrawn.

The Walla Walla No. 4 in Section 21 also contained water in the

[8] F. P. Fisher, consulting engineer, Mount Vernon, Ohio, from a joint report by A. A. Hammer and F. P. Fisher, November, 1930.

producing horizon with a slightly greater head because lower structurally. Wells drilled farther down dip also contained water. The well on the Benson Ranch northwest of the gas field, and considerably lower structurally, contained water in every porous horizon to a depth of 2,000 feet.

It is thus seen that there is a definite water table down dip from the gas field and a definite barrier to gas migration down dip outside of the productive area above the water table.

Observations made in a study of the operation of the field produces added evidence to substantiate the theory that low pressure is due to escaping gas. In his joint report with the writer previously mentioned, Fisher states:

> During the last eleven months approximately 60 million feet have been withdrawn from the field and sold. . . . During the active flow of this delivery a pressure has been established in the immediate area of the wells from 8 to 10 ounces lower than the seasonal low pressures with the field shut in, a condition wholly consistent with establishing a rate of flow through the very porous horizon with an accompanying drop of pressure from the fault zone back to the well area. An experiment concentrating all of the three compression units on a single well did not further reduce this pressure.
>
> All of these records of performance are consistent with the assumption that a relatively small portion of the total leakage is finding its way into this horizon so that a change in the rate of well delivery does not affect the pressure relations to an observable degree. Two important inferences may be considered as having been demonstrated by the observed behavior of this gas pressure and flow:
>
> First, a supply of gas is continuously rising through this fractured zone, part of which is now taken from the wells, and the balance escaping to the air too widely diffused for observation.
>
> Second, this escape of gas must necessarily have been continued for a long period of time, as no known changes of structure have occurred within the time of man's observation that would account for the initiation of this leakage.

Additional evidence supporting the previous explanation of the low pressure was found in the Northwestern Natural Gas Company's well No. 2, which was drilled closer to the fracture zone than any other well. In this well gas was encountered at a depth of 1,248 feet, in a zone lower than that from which the other wells produced, with exactly the same pressure as the gas from the shallower zone.

SUMMARY

The data herein presented are summarized as follows.

1. In the Rattlesnake Hills field the accumulation of gas has conformed with the well known law of anticlinal accumulation.

2. A variation of this law has been produced by the upward migration of the gas along fracture zones in the basalt and its accumulation in porous phases of basaltic flows.

3. The great displacement along the fault has thrown the zones that produce the gas on the downthrown side in a position close to the probable source rocks on the upthrown side.

4. The extremely low pressures are due to the escape of gas along fracture zones and to the fact that the gas has been escaping over a long period of time.

5. The most likely source of the gas is in rocks of Eocene age that lie below the principal basalt flows, or possibly in rocks of early Miocene age.

6. Evidence of an indigenous source in sedimentary rocks between basaltic flows is so meager and of such a remote character, when viewed in the light of known conditions, that little credence is given to this possibility.

7. No evidence has been found to warrant any assumption that there is any direct causal relationship between volcanic activity and the occurrence of gas, the volcanism simply being incidental to the occurrence.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 860-870, 6 FIGS.

GEOLOGY OF TWO BUTTES DOME IN SOUTHEASTERN COLORADO[1]

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ABSTRACT

The most prominent topographic feature in southeastern Colorado is a double-capped butte known as Two Buttes which rises abruptly 400 feet above the surrounding Tertiary plains. The butte is capped by sandstone of probable Triassic (possible Jurassic) age dipping 10° W.-NW.

Immediately southeast of the butte an igneous mass is exposed with an area of more than one-quarter of a square mile. The igneous rock appears to be andesite porphyry. It is locally in contact with a ledge of limestone and dolomite (Alibates) in which it has induced slight contact metamorphism. The porphyry has obviously pushed up the resistant dolomite and overlying beds and has spread out somewhat so as to form a laccolith. The resulting closure in the overlying sediments is about 800 feet. The age of the intrusion is probably late Miocene.

Slightly more than 900 feet of sediments is exposed within the small area of the Two Buttes dome. These sediments range from Permian (Whitehorse) through Mesozoic to Cenozoic. The geographic position of Two Buttes makes the exposed section valuable both to Mid-Continent and to Rocky Mountain geologists, serving as it does to link stratigraphic markers from both regions.

INTRODUCTION

The topographic feature known as "Two Buttes" (Fig. 1) lies in southern Prowers County, Colorado, on the northwest flank of a structural dome at the apex of which igneous rocks are exposed. The closure resulting from the uplift extends into northern Baca County, Colorado. Some of the best exposures of the pre-Cenozoic sediments are found in the latter county around the shores of Two Buttes reservoir.

The Two Buttes dome was mapped with plane-table and alidade in October, 1930. V. C. Benderoff assisted the writer.

PHYSIOGRAPHY

The double-capped butte consists of red shale and red, fine sandstone protected from erosion by massive-to-cross-bedded sandstone of Triassic or Jurassic age. The butte rises abruptly 400 feet above the surrounding Tertiary plains. The elevation of the higher of the two tips is 4,715 feet above sea-level. Two Buttes was apparently a

[1] Manuscript received, April 9, 1934. Published by permission of Shell Petroleum Corporation.

[2] District geologist.

monadnock during the deposition of the Cenozoic (Pliocene?) strata. Post-Pliocene erosion has bared the top of an igneous mass southeast of the butte.

FIG. 1.—Two Buttes. The more northerly of the two tips is visible at right of main butte-top. Alibates (Day Creek?) dolomite (*a*) largely covered with talus; overlain by Red-beds (*b*). Base of "Big sandstone" (*c*) caps the butte. Looking northwest from southeast side of butte.

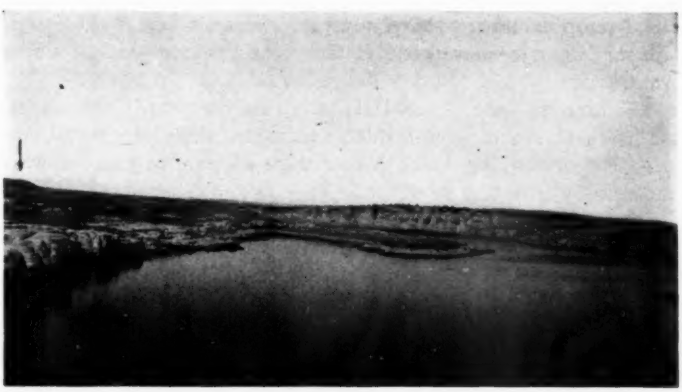

FIG. 2.—Two Buttes reservoir looking west from dam; shores visible in this photograph formed of "Big sandstone" (Triassic or Jurassic); arrow points to Morrison sandstone and shale above "Big sandstone." Photograph by C. L. Baker.

The principal drainage is that of Two Buttes Creek, which appears to have been antecedent, with slight monoclinal shifting since

the uplift. The younger tributaries, both to Two Buttes Creek and to the next main drainage line toward the north, show a radial pattern in relation to the combined topographic and structural "high."

EXPOSED SEDIMENTS

Cenozoic strata.—"Caliche," conglomerate, and related beds of probable Pliocene age[3] flank the uplift and overlap all the pre-Cenozoic rocks. A few boulders of dark porphyry resembling the porphyry of the exposed igneous core are present in the basal conglomerate of the Tertiary strata.

Quaternary sand and alluvium occupy strips locally one-half mile in width along the principal drainage (Two Buttes Creek).

Dakota sandstone.—This formation, presenting its usual characteristics, is present well down on the flanks of the uplift and is exposed along most of the drainage lines in southeastern Colorado. It constitutes a general east-dipping cuesta facing the Sierra Grande uplift (Cordilleran) and sloping toward the broad regional basin in western Kansas. The thickness is 80–100 feet. The Dakota may be distinguished in most places in southeastern Colorado from the older Purgatoire sandstone (Cheyenne) by the following characteristics: the Dakota is fine-to-medium-grained, whereas the Purgatoire contains lenses of coarse material; the big basal Dakota sandstone forms a bold scarp exhibiting sharply serrated forms, whereas the Purgatoire sandstone is more recessive and weathers into gently rounded forms.

The extreme base of the Dakota is rarely exposed, but consists of a 10-foot zone of even-bedded sandstone, shaly sandstone, and shale. The underlying, black Kiowa shale appears to grade upward lithologically into this sequence.

Purgatoire formation.—The outcrop of Kiowa shale is commonly represented by a grassy slope separating the Dakota and Cheyenne sandstone crops. The shale on fresh exposure is dark gray-to-black, and locally highly fossiliferous, especially with *gryphyae.* A thin conglomeratic sandstone is present just below the middle of the shale member. The Kiowa shale is 27–35 feet thick in most of the outcrops in southeastern Colorado, but thickens eastward and is about 50–60 feet at Two Buttes. It lies disconformably on Cheyenne sandstone in the immediate area of this report, but has been found to rest directly on Morrison greenish clay-shale in a few water wells in the plains

[3] C. L. Baker, personal communication.

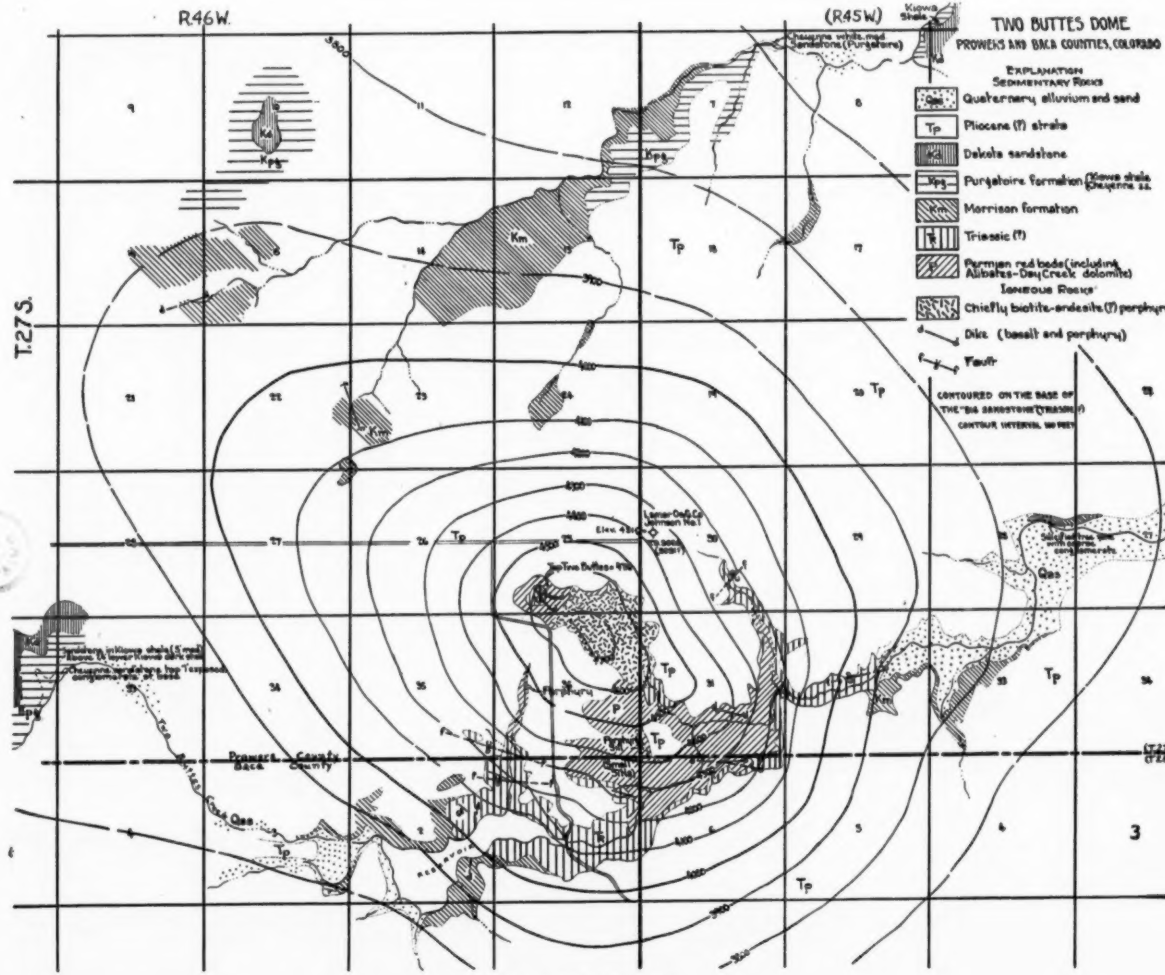

FIG. 3.—Geologic map.

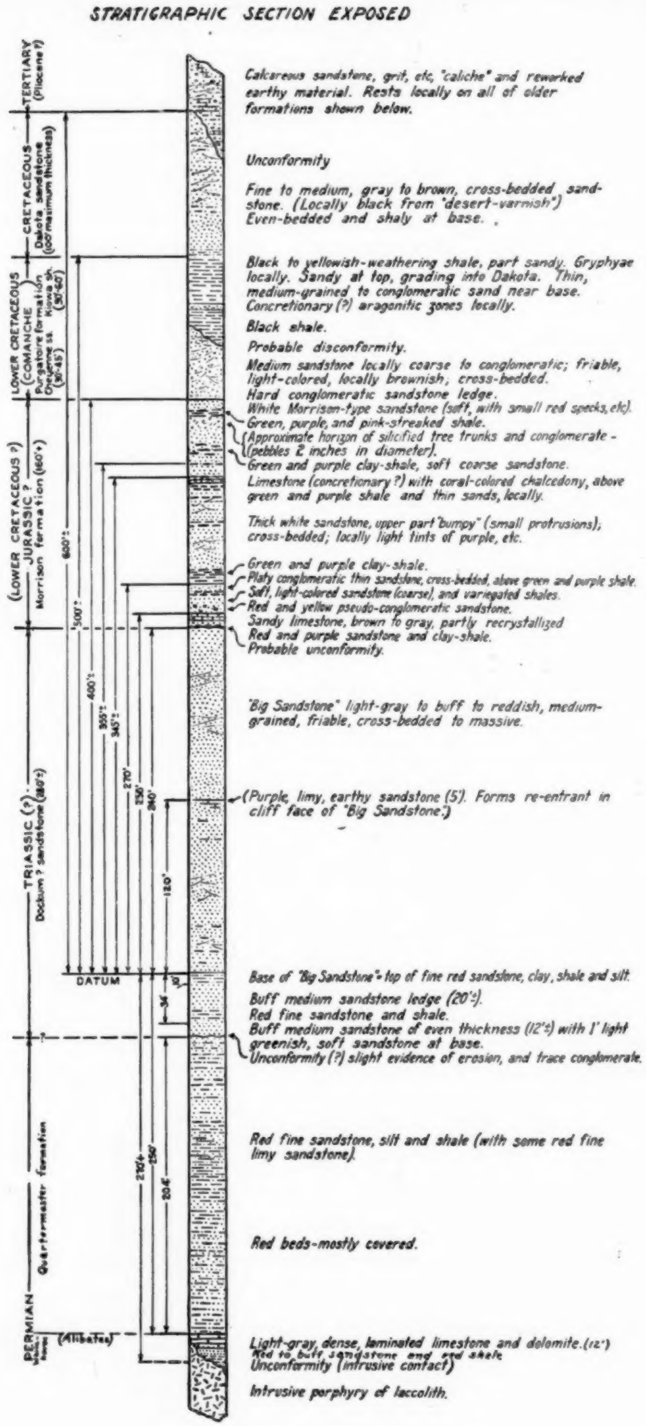

FIG. 4.—Stratigraphic section exposed.

country of Baca County, Colorado, and directly on Permian Red-beds in parts of Kansas.[4]

The Cheyenne sandstone is commonly white, friable, medium-to-coarse and conglomeratic (with pebbles up to 2 inches in maximum diameter) and is massive-to-cross-bedded. In some places the upper part is yellowish colored and locally is capped with hard, dark brown, ferruginous grit. The thickness averages about 50 feet, though water-well data from the surrounding plains indicate that in a few places it is thin or absent. This sandstone is the chief aquifer of southeastern Colorado.

The Purgatoire formation is generally considered to be of Washita age and is correlated with the Glencairn shale and Lytle sandstone of east-central Colorado.

Morrison formation.—The Morrison formation is characterized by green and purple clay-shales, soft white sandstones which are medium-grained to coarse and conglomeratic,[5] and by chalcedony concretions present in a few sandstone and thin limestone beds. In the Two Buttes area, a reddish sandy pseudo-conglomerate with distinctive "crinkled" texture is present at the base of the formation. The total thickness of the formation is apparently about 160 feet at Two Buttes.

The Morrison formation is probably of latest Upper Jurassic age, though it may be Lower Cretaceous (Comanche). It overlies the "Big sandstone" with probable unconformity.

"Big sandstone" (Triassic or Jurassic).—The gray-to-buff (locally reddish) medium-grained, friable, cross-bedded-to-massive sandstone which caps the buttes themselves, and which forms the rugged bluffs on the northwest shore of the reservoir constitutes the chief stratigraphic problem of the area. It is variously considered to represent either Exeter, Wingate, or Dockum sandstone. The present writer believes, for the following reasons, that it may be Triassic (Dockum). 1. It overlies even-bedded Red-beds of probable Permian age containing the Alibates (Day Creek?) dolomite. 2. It may apparently be correlated by means of well logs with the basal Triassic (Dockum) section logged in wells in Cimarron County, Oklahoma. 3. The widely transgressing Morrison formation overlapped beds progressively older eastward in Colorado and Kansas. The Morrison rests on Jurassic strata west of the Two Buttes area and on Permian beds in western Kansas. Between those two areas, as at Two Buttes, there should

[4] R. C. Moore, "Oil and Gas Resources of Kansas," *Kansas Geol. Survey Bull. 6*, Pt. II (1920), p. 76.

[5] A strikingly cross-bedded and conglomeratic zone near the top of the formation contains silicified tree trunks up to 30 feet in length.

be a zone wherein Morrison rests on Triassic. 4. If the "Big sandstone" is considered to be of Jurassic age, there is no appreciable section left to be classed as Triassic, and since a 575-foot section of Triassic beds is present in northwestern Cimarron County, Oklahoma, it appears somewhat unreasonable to postulate their complete absence in northern Baca County.

An erosion surface[6] with immediately overlying, slightly conglomeratic sandstone may be observed at Two Buttes at the base of the 12-foot buff, medium sandstone ledge which occurs above the lower Red-bed zone. (See diagrammatic stratigraphic section, Fig. 4.) This is tentatively chosen as the base of the Triassic (?) section.

Correlation of this sandstone, however, must still be considered an open question, since the lithologic character appears to favor Jurassic classification. Mica is not megascopically noticeable except in a zone a few feet thick at the base of the formation. The writer believes that even if this sandstone is found to be younger than Triassic, it is not the Exeter sandstone. The Exeter sandstone of the Cimarron Valley in Union County, New Mexico, is conformable with overlying undoubted Morrison beds and lenses out westward above typical Morrison-type variegated shale. The writer believes that the Exeter is a sandstone lentil in the lower Morrison formation. The "Big sandstone" at Two Buttes does not appear to have similar stratigraphic relationships.

Quartermaster shale.—A Red-bed section occupies the 200-foot interval between the top of the Alibates and the base of the "Big sandstone." Sandstones in that zone are red, fine-grained, and ripple-marked, with a few calcite veinlets. The sandstones are calcareous at a few horizons and alternate with red shale and red silt. This section is fairly well exposed in the SW.¼, Sec. 31, T. 27 S., R. 45 W. The lithologic continuity of this series does not permit subdivision of the zone, all of which probably belongs in the Quartermaster formation. The even-bedded character and the fineness of grain suggest Permian rather than Triassic correlation.

Alibates dolomite.—Correlation of the 12-foot ledge of limestone and dolomite (Fig. 6) at Two Buttes with the Day Creek dolomite of southwestern Kansas was first suggested by Frank C. Greene[7] after he had studied the writer's measured section and descriptions. Since that time, the writer has established to his own satisfaction the correlation with Alibates dolomite of the Texas Panhandle. The correlation of Alibates with Day Creek can not yet be proved in the field, but is

[6] Corroborated in the field by C. L. Baker.

[7] Personal communication.

believed to be almost certain. In so far as the writer is aware, this is the first published correlation of Alibates dolomite for any outcropping area in Colorado.

FIG. 5.—Two Buttes, looking north-northwest from the "Big sandstone" (in foreground). Left middle-distance (across valley) is basal sandstone series of "Big sandstone," overlying probable Permian Red-beds,—same stratigraphic section as that forming upper half of Two Buttes monadnock.

FIG. 6.—Alibates dolomite ledge; center of east line, SW. ¼, Sec. 31, T. 27 S., R. 45 W., Prowers County, Colorado. Buff-to-red fine sandstone (*a*); Alibates dolomite (*b*); basal Tertiary beds (*c*).

The thickness is comparable with measured thicknesses of Alibates dolomite in the western Texas Panhandle area. In the latter area, the

upper and lower members of the usual "double-ledge" are merged in a few places to form a single thick ledge similar to the Two Buttes crop.

Since the Alibates dolomite grades into gypsum mapped as Cloud Chief (as, for instance, in Armstrong County, Texas), and since the Cloud Chief is generally classed by field men as a member of the Whitehorse *formation*, the writer considers the Alibates to constitute the local uppermost member of the Whitehorse formation, rather than the basal member of the Quartermaster formation.

In the S. ½, Sec. 31, T. 27 S., R. 45 W., approximately 30 feet of Red-bed section is exposed below Alibates (Day Creek) dolomite. The upper portion of this section is buff-to-red, fine sandstone about 12 feet thick. The sandstone overlies red clay-shale and red shale. The lowest stratigraphic horizon exposed in the Two Buttes area is buff-gray, fine sandstone about 30 feet below the base of the Alibates. Only the top of the sandstone is exposed.

IGNEOUS ROCKS AND AGE OF THE INTRUSION

The area of outcropping igneous rocks is shown on the geologic map (Fig. 3). The main laccolithic mass is a porphyritic rock with phenocrysts consisting of large plates of biotite and elongate, translucent green crystals of hornblende in a gray dense groundmass. The porphyry exposures at Two Buttes all show rather advanced weathering. A truly fresh specimen can not be found. Thin sections have not been prepared but the rock is judged to be an andesite porphyry. It is apparently related to the large flows, such as that of Mesa de Maya, outcropping farther southwest in Colorado and northeastern New Mexico. The igneous activity of the latter area, ranging from late Tertiary into Quaternary time, has been described by Lee.[8] The intrusive mass at Two Buttes, where it underlies Alibates dolomite, has induced slight contact metamorphism in the dolomite. A few small tongues or stringers of porphyry intrude the Alibates. The igneous mass broke through the dolomite bed in one locality near the center of the west line, Sec. 31, T. 27 S., R. 45 W., where it is found in contact with the basal portion of the "Big sandstone." Small sills of porphyry have been intruded into the surrounding Red-beds, as for example in the NE.¼, Sec. 1, T. 28 S., R. 46 W. Basalt dikes cut the main porphyry mass and basalt and porphyry dikes likewise intrude, with a roughly radial pattern, all exposed sediments up to the overlapping Tertiary (Pliocene?) caliche. The latter formation con-

[8] Willis T. Lee, "Raton-Brilliant-Koehler Folio," *U. S. Geol. Survey Folio 214* (1922).

tains a few boulders of andesite porphyry probably derived from the weathering of the Two Buttes intrusive. From the foregoing considerations, it is apparent that the intrusion was post-Cretaceous and pre-Pliocene (?). Since the igneous activity toward the southwest did not make itself evident until late Tertiary, it is probable that the Two Buttes intrusion occurred in Miocene (probably late Miocene) time.

GEOLOGIC MAP

The geologic map (Fig. 3) shows considerably more detail and presents several revisions relative to earlier published maps. The Geologic Map of Colorado (R. D. George, 1913) distinguishes only the following formations in the Two Buttes area: "Permian-Pennsylvanian undivided," "Comanche," "Morrison," and " Dakota." The igneous rock is correctly shown on that map as "Tertiary intrusive lamprophyre." The Areal Geologic Map prepared for the Fourth Annual Field Conference, Kansas Geological Society, September, 1930, distinguishes in the Two Buttes area "Lykins formation (Permian," "Purgatoire-Morrison formations," and "Dakota sandstone." On the reduced scale necessarily used on that regional map, it is not clear whether the "Big sandstone" is mapped as Permian or Jurassic (Morrison), but it apparently is included in the Lykins formation (Permian). The igneous rock on the latter map is incorrectly shown as a Quaternary extrusive.

SUBSURFACE SEDIMENTS

The Lamar Oil Company's (taken over by Chesapeake Oil Company) Francis Johnson No. 1, SW. cor. NW.¼, Sec. 30, T. 27 S., R. 45 W., Prowers County, Colorado, on the northeast flank of the Two Buttes dome, started in lower Triassic (?) Red-beds, reached the Alibates dolomite at 260 feet, and penetrated igneous rock between 525 and 573 feet. This test has the following questionable correlations: Cimarron anhydrite, 1,290 feet; base Permian, 2,640 feet; base Pennsylvanian, 4,965 feet. The test was dry and abandoned at 5,020 feet (possibly 5,031 feet) in Mississippian limestone of probable Chester age. Several slight showings of oil and gas occurred in probable upper Pennsylvanian strata between 2,760 and 3,015 feet. The surface elevation is 4,310 feet.

STRUCTURE

Two Buttes uplift is a nearly quaquaversal dome, but with slight elongation northwest and southeast. The surface closure is approximately 800 feet. The apex of the dome is occupied by the intrusive

porphyry. The sediments dip away from the igneous core in general at the rate of 10° or more near the porphyry outcrop and at the average rate of 6° at a distance of one and one-half miles from the igneous core. Along the west edge of the outcropping igneous mass, the porphyry is in contact with the Alibates dolomite and may be seen in at least one small reëntrant in the dolomite crop to extend back several feet below the dolomite along a general stratigraphic plane. It is concluded that the small igneous mass ascended until the top of the rising mass encountered the hard Alibates dolomite. The igneous material then pushed the dolomite and overlying section upward, at the same time spreading out somewhat at the base of the dolomite. (Near the top of the dome, the porphyry broke through and reached the base of the "Big sandstone.") The result was a laccolithic dome. The structural closure on the Alibates and higher beds should therefore be found to be considerably greater than the closure on any stratigraphic plane lower in the section, although the whole section appears to have been uplifted somewhat. The interval from a marker such as the Cimarron anhydrite to the top of the Mississippian limestone is seen to be normal for the general area, indicating that the Two Buttes uplift is not a reflection of a pronounced primary "high." A slight primary "high" may possibly have been responsible for the localization of the igneous intrusion.

The roughly radial pattern of the dike system has been mentioned. This pattern is somewhat obscured by the number of nearly east-west dikes. These dikes follow the strongest joint system, which is N. 53°–80° W. Several small dikes are present in the main butte. Small-scale, normal faults are associated with some of the dikes. A few faults are present not associated with dikes. The faulting is believed to be of a superficial nature representing settling and readjustment after the intrusion.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 871-891, 10 FIGS.

GEOLOGY OF NATURAL GAS IN ROUMANIA[1]

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ABSTRACT

Only one-sixth of the 150 million cubic feet of gas produced per day in Roumania comes from the Transylvanian gas fields, the balance being produced with the oil in the various oil fields of the southern sub-Carpathian region, particularly the Dambovitza and Prahova districts. The largest producing gas horizon at present is the deeper "pay" (Meotic) of the old Moreni field. The Transylvanian gas fields produce from rocks of upper Miocene age. The gas is 97 per cent methane and is apparently not associated with oil. The gas derived from the oil fields occurs in close association with the oil (Moreni, Ochiuri), or as "dry" gas in a formation above the oil horizon (Aricesti, Boldesti).

The Transylvanian gas fields occur along the central domes produced by the folding of the Miocene and Pliocene beds in the Transylvanian basin.[3] The edge folds are steep, narrow, and closely packed, but toward the center of the basin these folds spread out and form a series of relatively broad domes suitable for the accumulation of gas. Forty-four such domes are known at present, of which 8 are proved, 5 are barren to a depth of 2,000 feet, and 13 are considered unfavorable.

The Roumanian oil fields, which are also the main producers of natural gas, occur in the southern sub-Carpathian region and to a smaller extent in the Carpathian arch. The most prolific zones are the Meotic and Dacic formations of Pliocene age. Most of the oil fields occur along narrow anticlinal structures, parallel with the general trend of the mountains. Many of these "structures" have a salt core, and the upper producing zone (Dacic) is oil-bearing only when pierced by the salt. The oil and gas in the lower producing zones (Meotic) is considered as of primary occurrence and these zones are productive along folds, faults, and other types of structure not necessarily associated with salt intrusions. The salt anticlines have so far

[1] Manuscript received, April 6, 1932, for the Association's symposium on the natural gas resources of the world—a volume whose scope was subsequently restricted to North America. The writer has given permission for its publication in the *Bulletin*. The writer wishes to express his thanks to George Boncescu, financial counselor of Roumania at Washington, D. C., for his valuable coöperation in securing data used in this paper, and to Frederick G. Clapp for constructive criticism of the manuscript.

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[3] F. G. Clapp, "Notes on the Natural Gas Fields of Transylvania, Roumania," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 2 (March-April, 1924), pp. 202-11.

contributed the largest percentage of the oil and gas produced in Roumania.

ECONOMIC HISTORY

On April 22, 1909, a well drilled on what is now known as the Sarmasel gas dome in Transylvania encountered a gas horizon (384 pounds pressure) at a depth of 992 feet. This well was the second test hole drilled by the Hungarian Government[4] in their prospecting program for locating potassium salt masses which crop out farther west and form the core of the marginal uplifts of the Transylvanian basin. The well was abandoned because of technical difficulties encountered in bringing the flow under control. It was not until 1910 that the Hungarian Government decided that the region should be further tested for gas production. The first five wells drilled that year were proved to be dry holes, but later drilling revealed the presence of gas in commercial quantities at Barna, Sarosul Unguresc (Magyar Saros), Copsa Mica, Samsudul de Campie (Mezö-Samsond), Zaul de Campie (Mezö-Zah) and Cristul Sacuesc.

Except for two small factories at Turda, which organized a small pipe-line company, no other local capital could be secured. As a result, in 1913 the Hungarian Government asked a group of English capitalists to investigate the possibilities of developing the Transylvanian gas fields, whereupon Alton S. Miller of Humphreys and Miller, Inc., and Frederick G. Clapp, came to make a survey of these fields. Miller and Clapp indorsed the findings of Professor Böckh regarding the presence of 36 well defined domes. The extent of these probable gas fields was given as 515 square kilometers and the total gas reserves estimated at approximately 2,200 billion cubic feet.

The latest estimates made by I. P. Voitesti and others raise these values to nearly 10,000 square kilometers (3,860 square miles) for probable gas territory and 9,500 billion cubic feet for total estimated gas reserves. The negotiations with the English group failed primarily because of political interference. In 1915 about half of the gas-field "structures" were leased to the Ungarische Erdgass Gesellschaft, a German group headed by the Deutsche Bank. Their concession included ten domes, only two of which—Bazna and Saros—are now being exploited. The capital invested to date by the U. E. G. is about half a million dollars. Eighty-five per cent of its stock is held by the National Methane Gas Society, the competing Roumanian governmental company. The latter company was organized in 1925 and owns all the land that had not been previously developed or leased

[4] Until 1918 Transylvania was a province in Hungary; it is now in Roumania.

to the U. E. G. By virtue of the Roumanian mining laws, all the subsurface rights of all undeveloped land belong to the State, and the State, because of having offered the land for exploitation, received about four-fifths of the company's shares.

The National Methane Gas Society is now exploiting the Sarmasel gas field on a very small scale. It is claimed that the present invested capital of $200,000 is not sufficient to assure proper development of the Transylvanian gas fields, and the Government's share is too large to assure adequate returns on the invested capital.

About 3,300,000 cubic feet of gas a day are used for domestic purposes. The small neighboring towns of Dicio-San-Martin, Medias, and Turda use natural gas for heating and lighting. The price set by the Government for natural gas is 25 cents per thousand cubic feet. For industrial purposes the price of delivered gas is less. About 20 million cubic feet of gas a day is used by small manufacturing plants located in the vicinity of the gas fields. Among them are factories for glass, cement, nails, and chemicals. Roumania has limited resources of coal and there is a big market awaiting the development of the natural gas industry.

Natural gas is also found in Roumania in association with the oil. At Colibas, in 1882, the Suchard Company encountered gas at a depth of 900 feet and had to abandon the well because of the high gas pressure. In 1890, at Aricesti, gas was encountered in a shallow well at a depth of only 30 feet. This gas kept on flowing through the plugged hole, but it was only in 1924 that the Romano-Americana (Standard Oil Company of New Jersey) drilled the first discovery well in this field to a depth of 2,200 feet. The well was making about 350 million cubic feet of gas a day when it caught fire, went to water, began flowing water and sand, and during several weeks deposited a 5-foot layer of sand over an area extending nearly 100 feet from the well. This field and the Boldesti field, both in the vicinity of Ploesti, are producing "dry" gas and no oil from the Dacic zone. A light oil was found in both fields in the Meotic horizon, 3,000 feet below the Dacic. The Aricesti and Boldesti gas fields were connected by pipe lines with the oil refineries and the city of Ploesti to furnish gas for heating purposes and for electric power plants.

Most of the gas produced in the oil fields was wasted because of primitive methods of production, which consisted of bailing and swabbing. When a well was flowing, the gushing stream of oil was thrown against a heavy copper bell located 20 feet above the casing inside the inclosed, but not gas-tight, derrick and the gases were allowed to escape. A law passed in 1929 forbids the waste of gas and regulates

the gas-oil ratios. The old methods of producing by bailing and swabbing are prohibited except in small fields. The application of the new law is not, however, as rigid as it reads. For instance, in the Moreni field, which is one of the oldest and best organized oil fields of Roumania, the total production of gas for 1930 was 1,172 million cubic meters. Of this, 180 million cubic meters, or 15 per cent, was used in the field, 196 million cubic meters, or 17 per cent, was sold and the balance of 796 million cubic meters, or 68 per cent, was blown into the air. About half of the gas produced was passed through absorption plants.

V. Patriciu[5] gives the following estimates of available gas reserves[6] by fields in the districts of Prahova and Dambovitza.

Field	*Gas Reserves in Million Cubic Feet*
Moreni	168,000
Piscuri	88,500
Gura Ocnitza	371,000
Valea Salciesului	76,000
Ochiuri	81,300
Baicoi-Tintea	117,500
Boldesti	1,180,000
Ceptura-Orzoaia	32,900
Filipesti de Padure	54,500
Floresti	84,700
Doicesti	66,800
Aricesti	787,000
Schiau-Valea Calugareasca	353,700
Calinesti	84,000
Margineni	403,500
Bucsani	378,500
Total	4,327,900

Figure 1 gives a graphic representation of these reserves.

The oil fields of the Buzau and Bacau districts each contribute about one per cent of the total output of gas in Roumania.

Less than one-third of the natural gas produced from the oil fields is utilized, although most of these fields are within less than 50 miles from Bucharest, the capital and largest industrial center of Roumania. Several factors might account for the present waste of gas, such as: oil operators being mostly interested in the recovery of oil, scattered small leases, highly competitive drilling conditions, shortness of the flowing life of the wells, and the fact that all main pipe lines are by law the property of the State. However, there is a pronounced tendency toward a better utilization of natural gas.

[5] "Contributions a l'inventaire des gisements petroliferes," *Annales des Mines de Roumanie* (November, 1931), pp. 449–55.

[6] Includes most important developed oil fields and some probable fields.

In 1928 only 17 per cent of the natural gas produced was used; this percentage increased to 26 per cent in 1929 and is still increasing. With the development of the Aricesti and Boldesti fields, with their potential oil and gas reserves controlled by only a few of the larger companies, it seems probable that a more rational development and use of the gas will result in the near future.

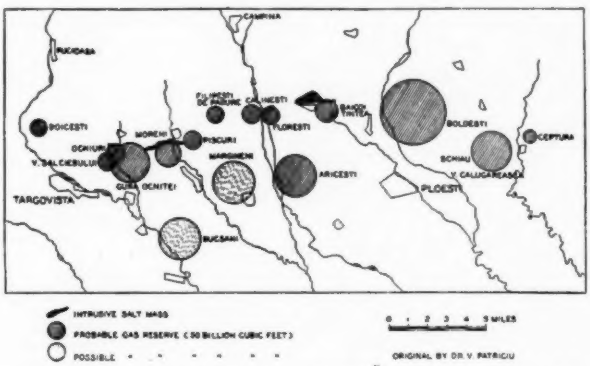

FIG. 1.—Map showing principal gas reserves in districts of Dambovitza and Prahova.

REGIONAL STRATIGRAPHY

TRANSYLVANIA

Quaternary.—The Quaternary includes terrace deposits, alluvium, and also loess near the base of the formation.

Pliocene.—The Pliocene is mostly fresh-water deposits of clays, sands, and soft coal beds.

Upper Miocene, Sarmatian.—The withdrawal of the Miocene sea left only scattered lakes, the waters of some gradually becoming fresh. In these lakes, sandstones and conglomerates were deposited along the borders and marls toward the center. Beginning in the Sarmatian, there was a general withdrawal of the waters in the Transylvanian basin toward the southeast corner.

Miocene.—The Miocene began with a general submergence of the Carpathian region, associated with considerable volcanic activity. On the west, large masses of andesite gave rise to the Apuseni Mountains. Thick beds of volcanic ash (Dacite tuff) cover the whole Transylvanian basin and occur interbedded with Lower Miocene clastic rocks. Volcanic activities extended throughout the Miocene period and to a smaller extent to the end of Pliocene or beginning of Quaternary

time. Lower Miocene begins with the basal conglomerates of the lower Mediterranean or Burdigalian. The upper Mediterranean or Helvetian is formed of alternating beds of gray unconsolidated sandstones, gypsum, and volcanic ash. At the end of the Burdigalian there was a general northern encroachment of the Miocene sea of short duration.

Oligocene.—The Oligocene contains calcareous marls, red clays, poorly consolidated yellow sandstones, and some conglomerates. On the northwest, at Huedin, the upper conglomerates include three beds of brown coal. On the southwest the important coal measures exploited at Petrosani are considered to be of Upper Oligocene age.

Eocene.—The Eocene comprises two alternating series of red clays, gypsum, and nummulitic limestones. The upper limestone also includes a few thin fresh-water beds. It occurs chiefly along the upper border of the Transylvanian basin.

SUB-CARPATHIAN REGION

Pliocene.—The Pliocene has four divisions.

1. Levantine (almost nothing to 1,500 feet)—calcareous marls, coarse sandstone, and conglomerates (fresh-water)
2. Dacian (1,000 feet)—coarse sandstones, soft coal, clays, and sandy marls (fresh-water)
3. Pontian (2,000 feet)—clays with *Cardium* and *Valenciennisia* (marine)
4. Meotian (1,000 feet)—green coarse sandstones, gray marls with *Helix* (continental), fine sandstones with *Neritina* and *Congeria* (brackish-water deposits), and marls with *Hydrobia*, sandstones and sandy marls with *Vivipara* and *Unio* (fresh-water)

Miocene.—The Miocene has five divisions.

1. Upper Miocene or Sarmatian (1,000 feet)—marls and clay with ripple marks, sandstones, conglomerates and limestones with *Mactra*. Sandstones form two-thirds of formation
2. Upper Helvetian—gray, sandy marls, sandstone, and white, light green or dark green dacite-tuff
3. Lower Helvetian—gray and red marls with gypsum
4. Lower Mediterranean or Burdigalian—conglomerates, sandstones, and sandy marls
5. Salifer (early Miocene or very latest Oligocene)—black clays and salt masses which crop out along marginal Flysch and in sub-Carpathian area

Oligocene.—The Oligocene contains coarse conglomerates with brecciated blocks, yellow and red calcareous shales which part very readily, showing small gypsum crystals along parting planes, a white, fine-grained sandstone (Kliwa sandstone), and black bituminous shales.

Eocene.—The Eocene contains shallow marine deposits, fine conglomerates, sandstones with orbitoids, micaceous sandstones, gray and black shales interbedded with sandstones, and marls with fucoids.

PRODUCING ZONES

TRANSYLVANIA

All the gas-bearing rocks of Transylvania are of Miocene age. The gas is secured from the Sarmatian, but deeper drilling is expected to reveal more gas in the Middle and Lower Miocene provided suitable reservoir rocks are present. This statement is based on the fact that gas showings occur along faults and the outcrop of salt masses, proving that gas occurs in the Lower Miocene as well as in the Sarmatian. On the fringes of the Transylvanian basin, oil seeps[7] were found near salt water springs (Lower Miocene), as well as in Oligocene, Eocene, and Cretaceous rocks. No commercial production was obtained from these rocks, but no wells have ever been drilled deep enough in any of the present fields to test these lower formations.

FLYSCH ZONE

As the occurrence of natural gas in the Flysch and the sub-Carpathian region is closely associated with the oil, a brief description of the various oil horizons is given.

The oil fields of the Flysch zone are located in the outer part or the margin, and produce chiefly from the Oligocene and in some places small quantities from the Cretaceous, Eocene, and Miocene rocks. The production of gas from this zone is only one per cent of the total production for Roumania.

Miocene.—Underlying the overthrust sheets of the Flysch zone the Miocene generally shows traces of oil at the contact with the Oligocene and is in places productive, as at Stanesti and along Halos River in the Bacau district.

Oligocene.—The Oligocene contains the richest oil deposits of the Marginal zone, which are probably of indigenous origin. Its lower part, which is the main producing zone in Galicia at Boryslaw and Tustanovici, is productive at Bustenari in the Prahova district and Zemes, Taslau, Moinesti, Solontz-Stanesti, and Targul-Ocna in the Bacau district. The main producing zone is the siliceous Kliwa sandstone (Upper Oligocene).

Eocene.—The Eocene is rarely productive and the oil is probably of secondary origin. Moinesti and Mosoarele (Bacau district) produce small quantities of oil from a micaceous sandstone of Eocene age.

Cretaceous.—The Lower Cretaceous contains small quantities of indigenous oil. In general this formation is bituminous in the region

[7] G. M. Murgoci, "Nouvelles donnees relatives aux gisements de petrole," *Analele Minelor din Romania*, Vol. 4, Nos. 8–9 (August, 1921), p. 948.

of the Alpine uplift, but only becomes an important source of oil in its westward extension toward the Caspian and Ural regions.

SUB-CARPATHIAN REGION

In the southeastern sub-Carpathian region (Bacau district), oil and gas are found in the Miocene (the salt formation and the Sarmatian) along closely folded anticlines, possibly faulted and occasionally overthrust. The production is invariably small.

In the southern sub-Carpathian region (Dambovitza, Prahova, Buzau districts) the Pliocene and Miocene are intensely folded, the salt formation intruding in places through all of the Pliocene rocks. It is along these folded and faulted "structures" that most of the Roumanian oil and gas is produced.

Pliocene.—The Pliocene has four divisions.

1. Levantine—where present, the oil is highly oxidized because of lack of suitable protective cover; consequently, very little, if any, accompanying gas
2. Dacian—important source of oil and gas of secondary origin. Oil occurs along salt structure only where intrusive mass has penetrated formation. "Dry" gas, however, has been found on anticlines with apparently no salt mass protruding through Upper Pliocene
3. Pontian—ordinarily unproductive because of lack of reservoir rocks
4. Meotian (Lower Pliocene)—principal oil horizon in southern sub-Carpathians (Campina, Arbanasi, Moreni, Boldesti), the oil probably being indigenous, although in fresh-water or brackish formation

Miocene.—The salt formation (Lower Miocene or Upper Oligocene) in places shows traces of indigenous oil, is rarely productive, and if so, in small quantities. The Sarmatian (Upper Miocene) in places shows traces of oil of secondary origin, is rarely productive, and if so, in small quantities.

REGIONAL STRUCTURE

TRANSYLVANIA

The Transylvanian basin (Fig. 2) is formed of folded Middle and Upper Miocene and Pliocene beds. The basin occupies an area of nearly 7,000 square miles. Around the edges crop out Eocene, Oligocene, and Lower Miocene rocks. The trend of the folds is north and south. Near the center of the basin the anticlines are broad, the prevailing dips being only 2° or 3° and the interval between the anticlines being almost 10 miles. Near the edges of the basin the slopes gradually increase, become vertical or even overturn, the marginal folds being overthrust toward the outside. Most of these marginal folds have a salt core, but in the central folds, which produce the gas, salt masses have not been encountered within drilling depth, although they probably form the core of the structure. The "structures" are

not regular. For example, an anticline breaks off and joins at right angles with some other anticline; or, several anticlines come together and branch off again, the resulting structure following a sinuous line. The prevailing trend, however, remains north and south. The principal gas domes of Transylvania are at the juncture of the east-west brachi-anticlines with the principal north-south anticlines.

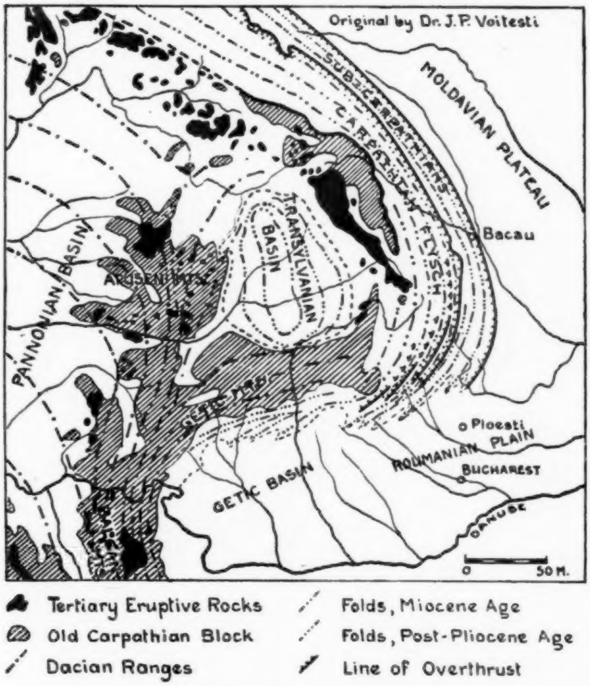

FIG. 2.—Tectonic units of Roumania and adjoining areas.

CARPATHIAN ARCH

The Carpathian arch is composed of three tectonic units.

1. Older crystalline and eruptive rocks with associated Paleozoic and Mesozoic formations, forming nucleus of inner part of Carpathians
2. Large belt of Cretaceous and Paleogene rocks (Eocene and Oligocene) forming so-called Carpathian Flysch. This belt extends without any break from Vienna depression southward, then westward, disappearing in region of Dambovitza River (80 miles northwest of Bucharest). From here on to Iron Gates the Carpathian arch is formed of crystalline Mesozoic mountains, which together with mountains of western Transylvania form a continuous chain (Fig. 2)

3. Complexly folded and faulted unit consisting of rocks of Flysch belt and Miocene rocks of eastern and southern sub-Carpathians. This unit is formed by an inner or lower belt (Cretaceous-Eocene) and an outer belt, the inner being overthrust upon the outer. The latter is composed of Oligocene and Eocene, is intensely folded, and in turn is overthrust upon base of salt formation (highest Oligocene or lowest Miocene) and of Middle Miocene formation

SUB-CARPATHIAN REGION

The sub-Carpathian region is represented by a series of hills surrounding the mountainous Flysch belt on northeast, east, and south. It is composed of folded Miocene beds on the north and east

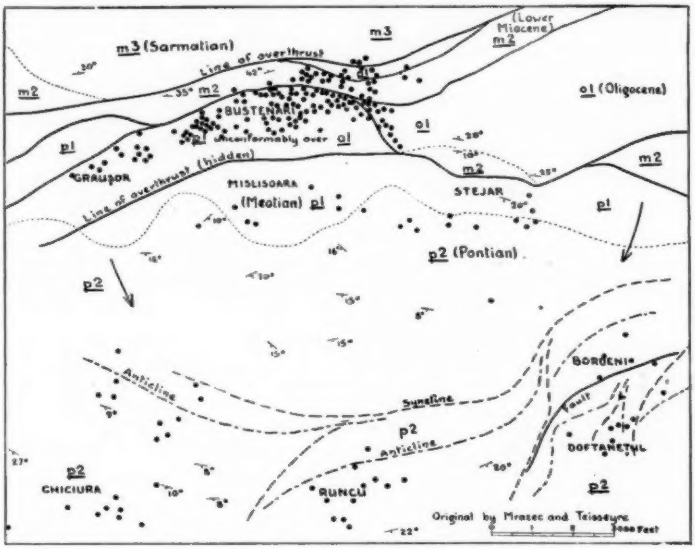

FIG. 3.—Map showing principal structural features of Bustenari-Runcu area.

and in the southern part the Pliocene is also included. The folding took place in the later Pliocene or post-Pliocene time.

With reference in particular to the oil fields, the structure of the southern sub-Carpathian region can be divided into three belts.

1. Belt of intense folding and faulting of rocks ranging from Eocene to Quaternary. Trend of these intensely folded rocks is parallel with general trend of mountains. Each fold is sheared along its axial plane and overlaps its neighbor like fish scales. Some block faulting in region. Oil occurs in any of rocks in contact with faults, provided they are sufficiently porous and are not too shattered. Largest production in this belt has been secured from Meotian (Lower Pliocene) and Oligocene. Campina-Bustenari area contains two main lines of dislocation, but tectonics of region are complicated by additional block faulting and presence of overthrust blocks of Creta-

ceous-Paleogene Flysch. Lower Pliocene beds crop out on south against this line of intense movement. These beds dip south, are folded, and folds gradually die out toward Roumanian plains. Several oil fields south of main area of displacement occur in Lower Pliocene beds (Meotian), for example, Runcu and Bordeni. In latter area, because of main tectonic movements on north (Fig. 3), Pliocene beds were squeezed and folded, resulting in simple structure considered as a whole, but showing very complicated detailed structure. Oil fields of the southern sub-Carpathian region, grouped under this first sub-division, are located along structures caused by tectonic movements. Salt masses might be present here and there but occurrence of such masses is incidental, and fields can not be considered as salt structure

2. Nearly 40 miles south of first belt, and parallel with it, extends the main belt of salt structure. Ochiuri, Moreni, Piscuri, Floresti, Baicoi are some of more important oil fields located along salt anticlines. Protrusion of salt masses has undoubtedly been caused by pressure exerted from north. They extend east and west, parallel with general trend of mountains. Salt masses do not form continuous unit. Some are several miles long, but in few places exceed a mile in width. At Baicoi, the salt mass protrudes almost like a dike, being only a few hundred feet wide. In places, salt mass cuts through whole series of Pliocene beds, and Upper Pliocene (Dacian) is only productive where in contact with salt mass. Lower Pliocene zone (Meotian) is productive even in absence of salt intrusion. Pliocene beds are dragged along by intrusive mass, and dips of beds range from 15° to 90°. Not uncommon for salt mass to be overthrust toward south (Fig. 4), in which case wells have to be drilled through salt before producing Pliocene rocks are encountered
3. Third belt is of same type as second belt excepting that folding is more gentle and there is not everywhere indication of salt core, although its existence may be suspected. There being no protrusion through Dacian rocks, this latter formation is barren of oil. However, Dacian contains "dry" gas in some places, the analysis showing 97–98 per cent methane with small amounts of ethane and carbon dioxide, but no heavier hydrocarbons. Deeper drilling has proved Meotian oil-bearing, although no indication of oil in Dacian. Aricesti and Boldesti are two of most important fields of third belt

DETAILED STRUCTURE OF GAS FIELDS

SARMASEL GAS FIELD

With its twenty-five drilled wells, the Sarmasel gas field is better known than any of the other gas fields of Transylvania. Its location

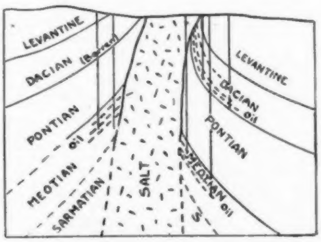

FIG. 4.—Cross section of Moreni oil field showing salt anticline with overthrust toward south.

is approximately 25 miles northeast of Turda. A general and a detailed cross section through the field are given in Figure 5 and Figure 6.

The Sarmasel dome is located on the Bazna Sarmasel anticline,

which extends northwest and has an elliptical shape with the long axis in the direction of the anticline. The dome is nearly 4 miles long and 2 miles wide. The wells are producing from the Sarmatian, which is represented by a series of blue clays, thin sand beds (Fig. 6), a few thin soft coal horizons and dacite tuff.

FIG. 5.—Generalized west-east cross section through Sarmasel gas dome.

The dips on the top of structure are very small and few exceed 2°, but on flanks of dome dips are increasingly greater and they also increase with depth. For example, in well No. 1, one mile southwest of well No. 13, the following dips were recorded.

Depth in Feet	*Dip in Degrees*
440	5
720	8
810	16
1,150	21
1,520	32
1,770	40
2,200	44

Although no salt formation was encountered in any of the wells, by analogy with the structure farther west (Fig. 5), it is generally admitted that the Sarmasel dome is also of the salt-dome type.

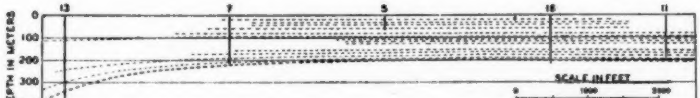

FIG. 6.—Cross section through Sarmasel gas field. Dotted lines show relative position of various sands.

The Sarmasel structure can be considered as typical for the Transylvanian gas fields. There are forty-three similar domes. Eight—Sarmasel, Moinesti, Sincai, Saros, Bazna, Nades, Daia, and Copsa Mica—are proved. In all these fields, with the exception of the last, the surface formation is Sarmatian. At Copsa Mica the wells are commenced in the Pontian (Middle Pliocene). The locations of these fields are shown in Figure 7. Thirteen domes are considered unfavorable because of the absence or partial erosion of the Sarmatian. Eighteen domes are considered favorable but have not been tested. The re-

maining five domes have no marked structural closure, although more defined structure may exist at greater depth.

BOLDESTI FIELD

The Boldesti anticline is located $5\frac{1}{2}$ miles north of Ploesti. It is about 8 miles long and extends N. 71° E. The structure can be considered as an elongate dome, the top of which is near Seciu and the axis of which plunges from that locality in both directions at an angle ranging from 2° to 6°. Two thousand feet north of the axis the beds dip 25°–30°. At nearly the same distance south of the axis the beds

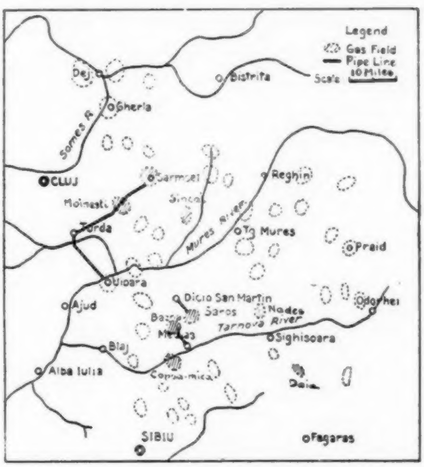

FIG. 7.—Sketch-map showing producing and probable gas domes in Transylvanian basin.

dip only 6°, but the dip gradually increases with distance and at about 4,000 feet distance the dip is 15°–18°. Figure 8 shows the location of the field. A cross section through Seciu and the Steaua Romana well No. 8 is shown in Figure 9.

At the surface the Upper Pliocene or Levantine crops out. Gas is encountered in the sands at the lower part of the Dacian. Several gas pays and two important gas-bearing zones were encountered in the Meotian. These zones are oil-bearing down the flanks.

ORIGIN AND ACCUMULATION OF GAS

In the Aricesti and Boldesti field "dry" methane gas is encountered in the Dacian formation. As already mentioned, the Dacian is

oil-bearing only where in contact with the intrusive mass of salt structure or along faults. All the evidence indicates that the accumulation of oil in the Dacian is of secondary origin, the oil having migrated upward from the Meotian or perhaps an older zone.

At Aricesti and Boldesti the occurrence of gas in the Dacian is not indigenous; however, there is no evidence of any intrusion or faulting in the area.

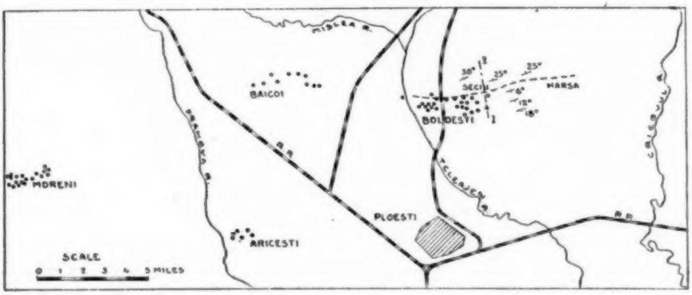

FIG. 8.—Sketch map showing location of Boldesti anticline.

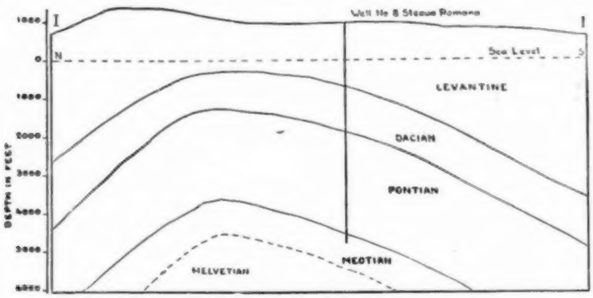

FIG. 9.—Cross section through Boldesti field.

Nearly 100 feet above the main producing zone there is a 20-foot coal seam. This coal horizon or a corresponding one is also encountered in the Moreni and Baicoi fields, each of which is oil-bearing in the Dacian. The average carbon ratio is about 45, but varies greatly from one coal seam to the other and greater variations are recorded in the same field than between Moreni and Boldesti. The presence of gas does not seem due to a higher degree of metamorphism.

Judging by the foregoing evidence, the writer believes that the gas has diffused from the Meotian through the 2,000 feet of water-wet

Pontian clays into the Dacian sands. By selective adsorption the heavier hydrocarbon molecules were retained by the clays and the water, whereas the light methane hydrocarbon molecules were able to diffuse through and accumulate in the upper Dacian horizons. A physical analysis of this phenomenon presents some interesting facts.

THEORETICAL CONSIDERATIONS ON SECONDARY GAS ACCUMULATIONS

The solubility of a gas in a liquid depends on the chemical nature of the gas and liquid and on the partial pressure of the gas. Methane is less soluble in oil or water than either ethane or propane. The analysis of gases accompanying the oil in the Meotian formation generally shows a much larger percentage of methane than ethane; consequently, the partial pressure of the first gas is greater than the partial pressure of the second gas. Therefore, the solubility of methane in water might be as great as, or possibly exceed the solubility of ethane or propane, although methane is the least soluble of the three gases.

Once in solution, both ethane and methane molecules are adsorbed along the surface of the clay particles because of the attraction resulting from the free energy available along the clay-water interface, and the attraction for the heavier hydrocarbons (ethane) is greater than the attraction for the lighter hydrocarbons (methane). Ethane molecules along the interface reduce the free energy available, therefore further reduce the attraction of the clay for methane molecules. Thus most of the methane molecules are free to move, while the other hydrocarbons are retained by the clay particles. Furthermore, as the rate of diffusion of small molecules (methane) is much greater than that of larger molecules, methane molecules travel faster and saturate the upper layer of water to a greater degree than do the ethane molecules.

The presence of gas in solution reduces the density of the water and the lighter water tends to move upward. When the water with gas in solution reaches the area of free gas it loses some of its gas, becomes heavier, and begins moving downward, thus creating convection currents which are very important factors in the migration of the gas through solution. The solubility of methane in water decreases with the decrease in pressure, and some of the gas diffusing through the water has to come out of solution eventually when reaching shallower horizons.

By considering the great thickness of the Pontian clays and the effect of selective adsorption, it is easily conceivable how methane gas could have accumulated in the Dacian without any of the other accompanying hydrocarbons being present. This phenomenon is par-

ticularly significant when considering the possibilities for oil in the Transylvanian gas domes.

The gas of Transylvania is also "dry" methane gas. It occurs in the Sarmatian. The gas domes supposedly have a salt core, but there is no apparent penetration of the salt core through the Sarmatian. Underlying the Sarmatian are the thick beds of clay of Mediterranean age. Along the fringes of the Transylvanian basis oil seeps were found in Eocene and Cretaceous outcrops at Zabala,[8] Ciuc, Ghimes, and other places. The oil seeps of Poiana Sarata are probably of Miocene age. It is not unreasonable to consider the possibility of deeper oil-bearing rocks associated with the upper gas fields of Transylvania, as the presence of "dry" methane can be easily accounted for and does not preclude the existence of oil.

WATER HORIZONS

In the Transylvanian gas fields no intermediate waters were encountered between the numerous existing gas sands. The only water recorded was edge water and surface water but even that water was associated with free gas, showing that the intrusion of water might have occurred during the period of drilling or development of the field.

At Boldesti and Aricesti there are a few important water horizons, and between these water sands the gas occurs in any rock of sufficient porosity. In these fields unconsolidated sandy clays and marls form good reservoir rocks.

GAS VOLUME, PRESSURE, AND RECOVERIES

TRANSYLVANIA

The gas-bearing rocks of the Sarmasel field are grouped into four gas zones according to their pressure and yield. The first group comprises the shallow sands to a depth of about 500 feet. The average pressure of these sands is nearly 220 pounds and the yield per well about 350,000 cubic feet per day. In most wells this upper zone, comprising on an average eight or nine thin sand horizons, is generally cased off.

The second gas zone extends from 500 to 660 feet. The average pressure of the four gas sands in this zone is nearly 340 pounds per square inch and the yield of some wells reaches 3.5 million cubic feet per day.

The third zone extends from 660 to 1,000 feet. Well No. 2 was com-

[8] G. M. Murgoci, *Analele Minelor din Romania*, Vol. IV, No. 8, p. 949.

pleted in 1908 in this zone. It had an initial rock pressure of 400 pounds per square inch and an initial production of 30 million cubic feet a day. At present the pressure is only 260 pounds. Well No. 16, completed in 1921 in the same zone, had an initial production of nearly 25 million cubic feet. The rock pressure was 350 pounds.

The fourth zone extends from 1,000 feet down. The deepest well drilled is No. 26, which went to a depth of 2,950 feet. Most wells in this zone are completed at depths ranging from 1,300 to 1,500 feet. The initial production of these wells varied from 20 to 25 million cubic feet a day with an initial rock pressure varying from 650 to 700 pounds per square inch. In the Bazna field, well No. 9, completed in 1926, registered a pressure of 435 pounds and an initial production of 32 million cubic feet. In the Saros field the initial rock pressure of the thirteen completed wells ranged from 400 pounds to 715 pounds per square inch, corresponding with a range in depth from 640 to 1,255 feet.

The Sincai dome has temporarily been abandoned. The maximum yield obtained from the discovery well drilled to 1,200 feet was 3 million cubic feet of gas. Two deep tests were proved to be dry holes, one of them—well No. 4—at a depth of 2,206 feet.

The total annual gas production of Transylvania has decreased from 7.9 billion cubic feet in 1930 to 5.7 billion cubic feet in 1933.

SUB-CARPATHIAN REGION

During the summer of 1931 Moreni produced nearly 175 million cubic feet of gas a day. Most of this gas came from the so-called Third sand of the Meotian. Figure 10 shows the central area of the Moreni field with the location of wells producing from the Third sand and the area south of the salt. Near the top and center of the developed area is the Standard's Romano-Americana well No. 160, which caught fire and kept burning for more than two years. The line *A-A* shows the approximate limit of the free gas zone, and the wells north of the line are gas wells and are not producing at present. The wells between the lines *A–A* and *B–B* are producing from the same "pay" with a gas-oil ratio of more than 9,000 cubic feet of gas per barrel of oil.

In 1930 many of the wells located south of the line *B–B* had a gas-oil ratio of 700 cubic feet or less, but a year later at least half of these wells showed an increase ranging from 50 to 100 per cent. On an average, the gas-oil ratio for the Moreni field, including the production from the Dacian, is nearly 2,000 cubic feet.

The available data on gas production derived from the oil fields

are incomplete. The Government estimates the total volume of gas produced from 1919 to 1929 to have remained constant at nearly 190 million cubic feet a day. A better figure might be determined by using the average gas-oil ratio values and the oil production figures which are generally available.

In the Boldesti field all of the gas at present is produced from the Meotian in association with the oil, although some "dry" gas has been produced in the past from the Dacian. The first three sands occurring at 25 feet, 80 feet, and 160 feet below the top of the formation, are gas-bearing on top of the "structure" and are cased off. The fourth

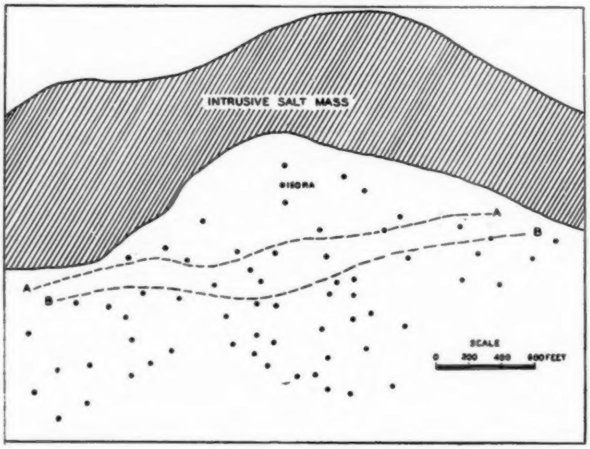

FIG. 10.—Sketch map of Moreni oil field south of salt, showing location of wells producing from Meotian, and limits of gas zone.

sand, 290 feet from the top, is gas-bearing along the upper part of the structure and oil-bearing down on the flanks. The Shell well No. 51-AR, producing from several oil sands, with a gas-oil ratio of more than 17,000 cubic feet, is presumably producing most of its gas from the 290-foot or Fourth sand.

The gas-oil ratio for Boldesti is higher than in most other fields and approximates an average of 5,200 cubic feet per barrel of oil. In general, the gas-oil ratio increases with the age of the well. There are a few small wells producing with a gas-oil ratio as low as 700 and there are a few of the larger wells that have produced with a gas-oil ratio of 1,500. The flush production conditions of the field and the locations of the wells close to the top of the structure cause the high average gas-oil ratio. The average operating tubing pressure is 260

pounds, with a minimum of 73 pounds and a maximum of 550 pounds. The casing pressures range from 440 pounds to 1,530 pounds. Initial rock pressures as high as 3,000 pounds are said to have been recorded in some of the wells completed to the Meotian.

UTILIZATION

Transylvania produces, on an average, 200 million cubic feet of gas a day. Of this gas nearly 10.5 per cent is used by local industries and only 1.6 per cent is used for domestic heating and lighting purposes. The following four short pipe lines connect the gas fields with near-by towns.

Pipe Line	*Year Completed*	*Length in Miles*	*Diameter in Inches*
Sarmasel-Turda-Uioara	1914	45	10 and 5½
Saros-Dicio San Martin	1917	7.6	16
Bazna-Medias	1918	3.2	14 and 5½
Sauca-Tg. Mures	1928	20.5	14 and 10

The Sarmasel-Turda-Uioara line transports 15 million cubic feet of gas a day. It has two intermediate compressing stations, one at Turda and one at Uioara. The line pressure varies from 170 to 210 pounds per square inch at the intake and from 30 to 90 pounds at the outlet.

In the oil-field region each company has its own pipe lines ranging in size from 2-inch to 20-inch. These lines take the gas from the wells to compression stations, to boiler houses, or to gas-lift wells. There are also a few lines connecting the fields with the refineries: Moreni-Campina, a 19-mile line owned by the Steaua Romana; Moreni-Ploesti, a 24-mile line owned by the Astra Romana (Shell); Boldesti-Teleajen, a 5-mile line owned by the Romana-Americana (Standard); and others. There is an obvious lack of main gas lines connecting the more important fields with the various industrial centers of the country. The reason for this may be traced to the fact that because of the mining law all principal oil and gas lines belong to the Government and must be operated under governmental control.

COMPOSITION AND PROPERTIES

The following table shows various analyses of natural gas from Transylvania.

Field	CH_4	C_nH_{2n}	O_2	H_2	N_2	He_2	*Analysis by*
Transylvania:							
Sarmasel No. 2	99.00	—	.40	.40	.20	—	Schelbe, 1909
Sarmasel No. 2	99.12	—	.15	—	.73	.001	Czako, 1919
Sarmasel No. 2	99.10	—	.12	—	.78	—	Spanco, 1928
Sarmasel No. 5	99.10	Traces	.53	—	.37	—	Budai, 1912
Sarmasel No. 7	98.94	—	.83	—	.23	—	Budai, 1912
Bazna No. 2	97.90	1.50	.60	—	—	—	?

The analysis of gas from Ariscesti shows:

	Per Cent
Methane	95
Ethane	2
Carbon dioxide	3

The analysis of natural gas produced with the oil from the Meotian Third sand at Moreni shows the following.[9]

	Per Cent
Methane	74.0
Ethane	10.8
Propane	4.2
N. butane	3.0
Iso. butane	2.0
Pentane	4.0
Carbon dioxide	2.0

Traces of carbon monoxide, nitrogen, sulphur, and helium

The gasoline content of the Moreni gas varies from 1.3 to 1.65 gallons per thousand cubic feet for production from the shallow Dacian rocks and from 0.55 to 0.90 gallons for the gas from rocks of Meotian age. Undoubtedly the diminishing pressures in the lower sands will result in an increase in gasoline content. At present nearly 90 million cubic feet of gas are passed through five absorption plants, with a daily output of 47,500 gallons of gasoline.

The Aricesti gas has a heating capacity of 880 B.t.u. per cubic foot and the Transylvania gas has an average of 920 B.t.u. per cubic foot.

WATER

At Sarmasel, in Transylvania, several water sands were encountered in well No. 1, drilled low on the dome to a depth of nearly 1,500 feet. In well No. 2, which was the discovery well and which is still producing, very little was encountered in some of the shallow sands. The analysis of the waters from the two wells follows.

	Well No. 1 Parts Per Million	*Well No. 2 Parts Per Million*
K	.00046	.00021
Na	.02528	.02559
Ca	.00162	.00141
Fe	.00014	—
Cl	.04517	.04565
SO_4	.00603	—
CO_3	.00048	.01125

In the Roumanian oil fields of the sub-Carpathian region, numerous water sands are encountered. The top and intermediate waters

[9] C. Popovici, "L'exploitation des gas dans les champs petrolifere," *Annales des Mines de Roumaine*, No. 7 (1931), pp. 385–87.

are generally brackish and the edge and bottom waters are generally high in sodium chloride.

DEVELOPMENT

Drilling in Transylvania is done with the hydraulic percussion system using a 35–40 H. P. gas engine and more recently with rotaries. A very special method of cementing water strings is used which requires the setting of many strings of casing. For example, in well No. 14, at Sarmasel, eight strings of casing were used; the surface string was 12-inch and the producing string was 4-inch. The hole is only slightly more than 800 feet deep. Well No. 7 at Bazna is only 617 feet deep and its completion required seven strings of casing; the diameter of the surface string was 14 inches.

The string of casing that is to be cemented is provided at its base with a special shoe much larger than the size of the casing and on top of the shoe a hemp packer is set. The casing is lowered in the hole and larger casing is inserted between the string to be cemented and the hole. This second string is used to pack the packer and also for circulation and cementing. As cementing proceeds, the intermediate string is withdrawn.

In the oil fields of the sub-Carpathian region, most of the drilling is done with improved rotary drilling equipment. The practices are very much the same as those in the oil fields of America.

In January, 1929, in the Ochiuri field, out of 4,700 feet drilled during the month, 1,100 feet were drilled with rotary equipment. In January, 1931, in the same field, 2,750 feet were drilled with the rotary out of a total of 2,800 feet.

The spacing of wells is very irregular. In Transylvania, at Sarmasel, some of the wells are 1,000 feet apart or less and the wells follow the local topography, being located mostly along the valleys. In the oil fields, some of the wells are drilled only 100 feet apart, but the tendency is to space the wells at 165 feet or 50 meters, particularly in the areas of deeper drilling. At Boldesti and Aricesti the wells are spaced 1,000 feet apart.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 892-907, 8 FIGS.

NATURAL GAS IN POLAND[1]

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ABSTRACT[3]

The gas-bearing areas in Poland are located on the northeast flank of the Carpathian Mountains, a region which extends geologically into Roumania. There are three belts in this province. About 100 oil-producing areas are scattered about in the two western belts, many of which also produce gas either with oil from common reservoir rocks or without oil from reservoir rocks above the oil-bearing series.

Rocks of Cretaceous and Tertiary (Eocene) age produce oil and gas in the western ("Median") belt. The Siary field produces gas and oil from rocks of Cretaceous age; Sekowa from Eocene and Cretaceous formations; and Potok from the Eocene. But the Sadkowa-Bialkowka-Brzezowka-Mecinka-Jaszczew fields (Jaslo district) produce only gas from rocks of Eocene age.

The central belt ("Marginal") produces oil and gas from rocks of Tertiary (Oligocene and Eocene) and Cretaceous ages; notably in the Boryslaw, Tustanowice, and Mraznica fields. Of these Mraznica ranks first.

The eastern belt ("sub-Carpathian") produces gas only from reservoirs in the upper part of the Miocene series at Daszawa and Kalusz. Wells have not been drilled deep enough to encounter rocks of Oligocene, Eocene, and Cretaceous age that are oil- and gas-bearing in the two western belts.

Poland is primarily an oil-producing state. Natural gas has been produced in the Carpathian region of Poland since 1912. Most of the gas produced prior to 1916 was wasted to the atmosphere, but since 1916 increasing amounts have been used for fuel purposes. The longest gas pipe line extends from the Daszawa field to the city of Lwow, a distance of 100 kilometers (about 62 miles).

INTRODUCTION

The occurrence of oil in the Carpathian region of eastern Europe has been known for a long time. It was first obtained from seepages and dug pits. The presence of natural gas has been known since the beginning of development on a large scale, about 1860. Here, as elsewhere, natural gas was considered a hindrance in the drilling of wells and the operation of oil wells. During the early history of development attempts were made to kill gas-bearing zones by introducing water. This method of development, at that early period, resulted in large wastes of natural gas into the atmosphere, estimated as several thousand million cubic meters.

[1] Manuscript received, January 18, 1932, for the Association's symposium on the natural gas resources of the world—a volume whose scope was subsequently restricted to North America. The manuscript has been revised (January, 1934) and the author has given permission for its publication in the *Bulletin*.

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[3] Prepared by Henry A. Ley.

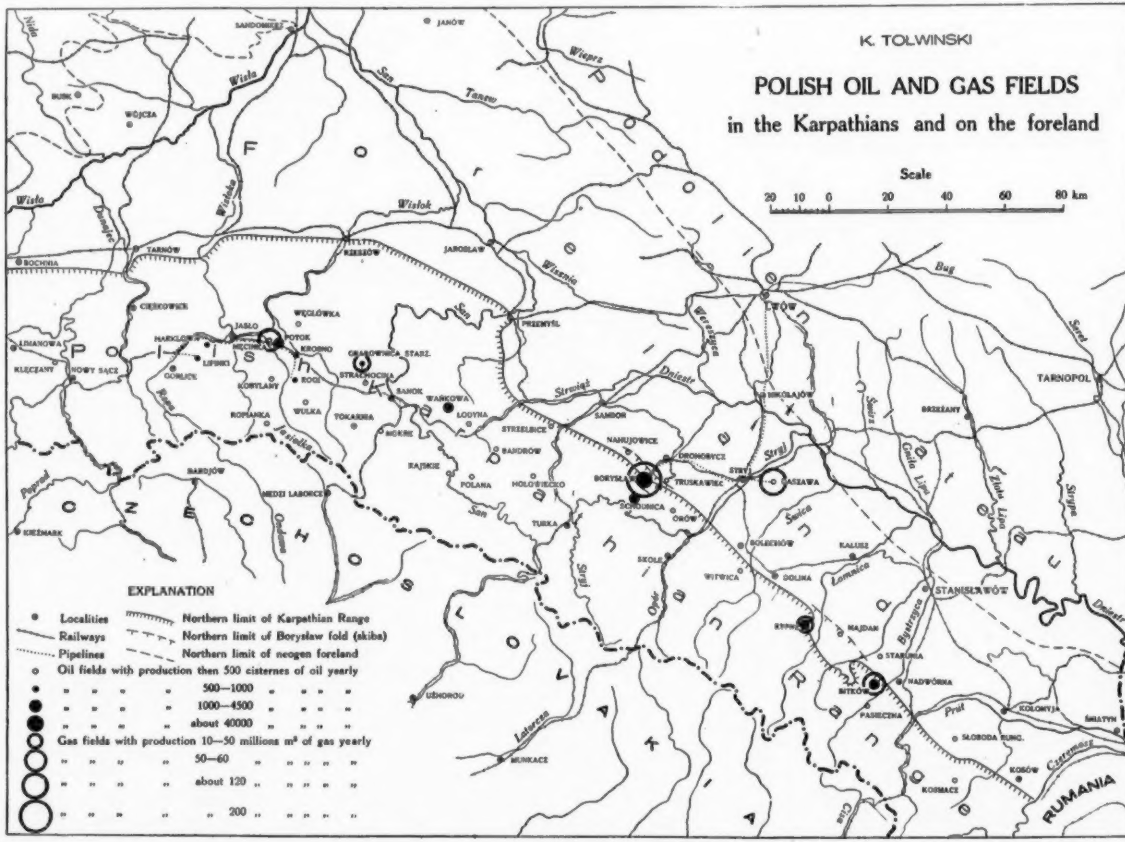

FIG. 1.—Map showing Polish oil and gas fields in Carpathians and on foreland. (Carpathian Geological Survey.)

Acknowledgments.—Statistics of natural gas produced in Poland were collected and published by the Bureau of Mines (Poland). The illustrations showing the Potok anticline and gas fields were prepared by J. Obtulowicz. The map showing development at Daszawa and the charts showing gas-well data were kindly contributed by J. Kowalczewski and M. Gawlinski.

GEOLOGY OF POLISH CARPATHIANS

The stratigraphy and structure of the gas-bearing region in Poland are briefly described in this paper. Geological conditions in several of Poland's largest gas fields are taken as examples. Figure 1 shows the location of the oil and gas fields.

The extent of the Carpathian Mountains within Poland is about 500 kilometers, but the area of the oil and gas fields of the Carpathians here may be considered to be 15,000 square kilometers.

Descriptions of the geological formations in the Carpathian Mountains can not be given in this paper. Most of the rocks in the Polish Carpathians are of Tertiary (Oligocene and Eocene) and Upper Cretaceous age. Rocks of Miocene age are not important in this region.

The Carpathians form a folded mountain system including, in some places, complicated structural forms. In the oil and gas region of the Carpathians there are two important tectonic belts: the Northern Skiba region and the Western Carpathians.

A. NORTHERN SKIBA REGION

This region consists of thrust folds. The folds are often expressed as large blocks, which extend for hundreds of kilometers. They are characteristic, differing, for example, from the Alpine overthrusts, and therefore they are here given the distinctive name "skiba."

In the northern part of a deep skiba near Boryslaw there are important oil- and gas-bearing horizons. Figures 2 and 3 show the character of the northern skiba.

The writer wishes here to call attention to the so-called deep element or skiba at Boryslaw. This is an overturned fold pushed over younger formations of the foreland and overlain also by Carpathian masses. The three principal reservoirs of oil and natural gas at Boryslaw occur in this skiba.

1. *Boryslaw sandstone near base of Menilite shales.*—The Boryslaw sandstone zone has an average thickness of about 20 meters. It is fairly porous, but the porosity is variable, and production is erratic. Some wells have produced more than 20,000 wagons of oil and large

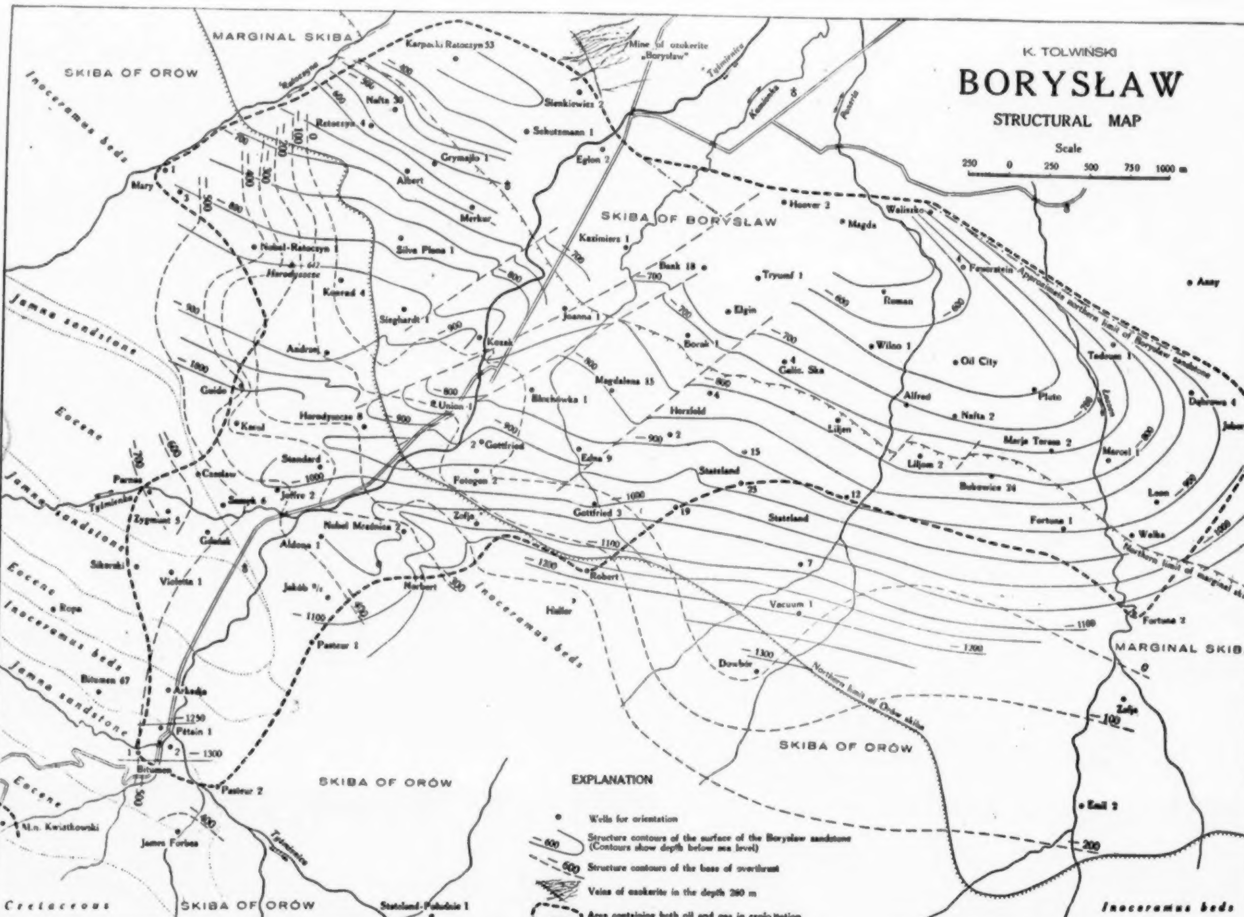

FIG. 2.—Map of subsurface structure, Boryslaw field. Southwest-northeast geological section of this area is shown in Figure 3. (Carpathian Geological Survey.)

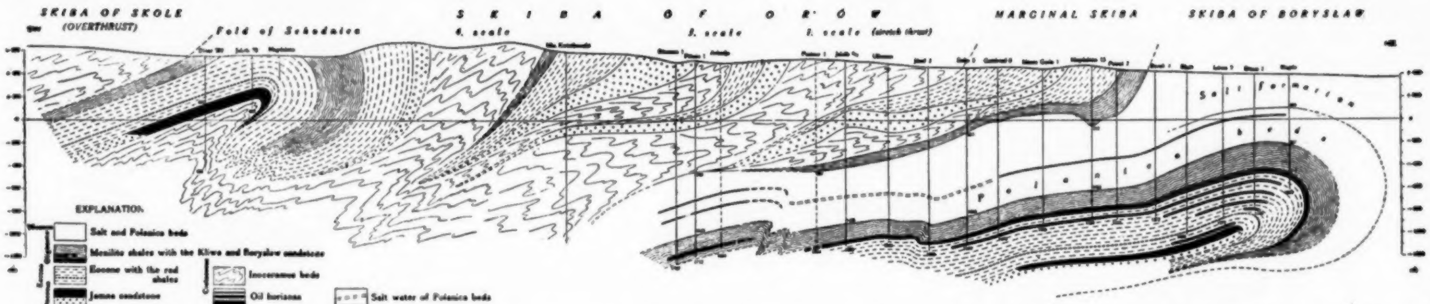

FIG. 3.—Geological section, showing structure of Northern Carpathian Range in Boryslaw region. Length of section from Dinar 382 at southwest to Magda at northeast end is approximately 9,900 meters, or 6 miles. Locations of wells in section are shown on subsurface structure map (Fig. 2). (Carpathian Geological Survey.)

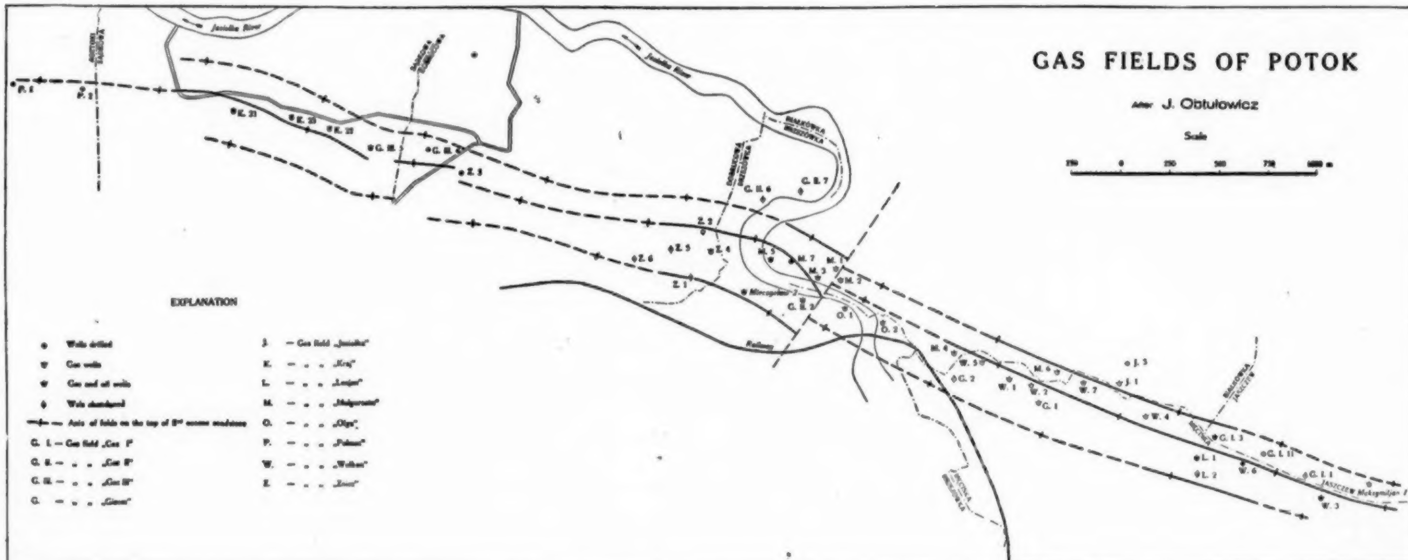

FIG. 4.—Map showing gas fields of Potok and synclinal folds of Eocene sandstone. (Carpathian Geological Survey.)

quantities of natural gas, but other wells in the same region have produced only small quantities. Accumulation was controlled by structure.

2. *Eocene horizons.*—The Eocene rocks are somewhat creviced. The oil and gas occur chiefly in joints and in free spaces between the beds. Thick sandstones are not found in the Eocene.

3. *Jamna sandstone on flank of Boryslaw fold.*—The Jamna sandstone is fine-grained and porous. Its thickness varies from a few meters to about 30 meters. Accumulation is up-dip, with salt water only in the structurally low wells.

Production of oil and gas is most widespread from the Boryslaw sandstone, extending over an area of about 15 square kilometers.

The Carpathian overthrust masses consist, in this external zone, of two large tectonic elements, namely the marginal skiba and the skiba of Orow. The skiba of Orow is a complicated structure. On the southern folded limb of the Orow skiba there are prolific oil-bearing horizons at Schodnica and Urycz. They occur in the Jamna sandstone of Upper Cretaceous age.

The element of the Boryslaw skiba extends for a long distance in the Carpathian Mountain region, northwest and southeast from Boryslaw. About 100 kilometers southeast of Boryslaw, at Bitkow, there are gas- and oil-bearing horizons in the folded Boryslaw skiba. There are three, or perhaps more, folds in the southern region of this element, which contain gas.

B. WESTERN CARPATHIANS

South of the outer folded region, called the Northern Skiba region, there is a large central depression. The surface rocks are largely members of the Krosno formation of Oligocene age (gray calcareous shales and sandstones). But on the transverse culminations there are narrow anticlines on which older Eocene and Cretaceous rocks are exposed. Oil- and gas-bearing reservoirs occur on these anticlines. One of these anticlines—the anticline of Potok, extending from Jaslo to Krosno—has numerous gas-bearing horizons over an area about 7 kilometers long.

This element is a narrow and steep anticline. On the apex of the anticline Eocene rocks are exposed; on either flank Menilite shales and the Krosno formation.

Figures 4 and 5, after J. Obtulowicz, give the geology of the Potok anticline. The map (Fig. 4) shows the synclinal folds of Eocene sandstone; the cross section (Fig. 5) shows the structure of the entire anticline. The gas-bearing horizons in the Lower Eocene and Upper

FIG. 4.—Map showing gas fields of Potok and synclinal folds of Eocene sandstone. (Carpathian Geological Survey.)

Cretaceous sandstones are shown. They occur at depths of 700–1,000 meters.

FORELAND

In the wide foreland region, covering about 20,000 square kilometers, the surface rocks are largely Miocene in age. The older salt

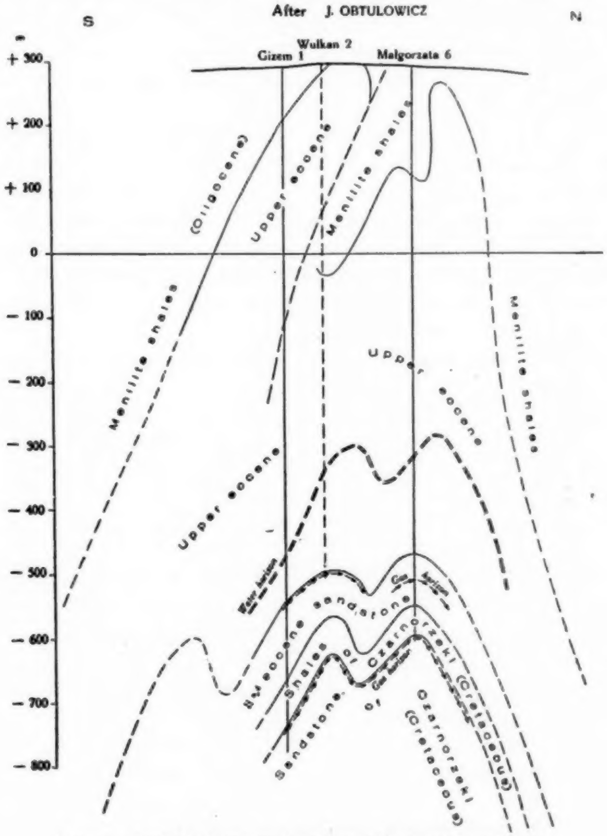

FIG. 5.—Geological section (south-north) of Potok anticline, showing gas horizons.

formations of the Lower Miocene (Helvetian) are found only in the southern zone, near the Carpathian Mountains, especially the eastern part. The southern zone is more intensively folded, some of the folds appearing to have the character of diapir folds, but in the northern

zone, where there is an unconformity with the Upper Miocene, the folds are larger.

In recent years, large gas fields have been discovered in Daszawa producing from rocks of Upper Miocene age. A gas field about 5 kilometers in length has been developed. Gas here occurs in several horizons, but the principal gas-bearing horizon is found at a depth of 700–800 meters in fine-grained sandstones separated by soft shales. The principal gas-bearing sandstones have not been completely penetrated and their thickness is not known. The rocks penetrated have a slight dip of a few degrees only.

The entire foreland region is covered with a mantle of diluvium deposits which preclude satisfactory geological studies at the surface. Here exploratory work must be guided by geophysical studies. There is little doubt that this belt is favorable natural gas territory. About 50 kilometers (31 miles) southeast of the Daszawa district at Kalusz, indications of gas have been found. The foreland regions cover about 20,000 square kilometers and objectives are in rocks of the younger Miocene formations.

PRODUCTION

Most of the petroliferous areas in the Carpathian region of Poland produce both oil and gas. The oil is usually accompanied by large amounts of natural gas; this is true, for example, at Boryslaw. In some places, however, gas only is produced for a time, but later, the wells produce oil, as on the Potok anticline.

In the foreland area of the Carpathian region only one gas field has been discovered. This field produces a "dry" gas, largely methane, and free of oil.

PRODUCTION OF NATURAL GAS AT BORYSLAW

Boryslaw has produced 23,500,000 tons of oil (1886–1932), and more than 4,500 million measured cubic meters of natural gas for the period 1916–1932. The total quantity of gas produced at Boryslaw, inclusive of the large quantity of gas wasted prior to 1916, is estimated at 10,000 million cubic meters. More than 1,000 producing wells have been completed at Boryslaw. These are estimated to have produced an average of 4 million cubic meters per well for the period 1916–1932.

Prior to 1916 pressures were not measured. Notwithstanding the long period of gas production at Boryslaw, the district is still producing 200 million cubic meters of gas annually. Some wells at Mraznica produce gas at the rate of 20 and more cubic meters per minute.

According to statistics showing the annual production of oil and gas in 1928, an average of about 60 cubic meters of gas are produced with 100 kilograms of oil. The same gas-oil ratio prevails in all other gas and oil fields in Poland.

In the United States of America, according to the statistics of the Bureau of Mines, the average gas-oil ratio was only 2.9 cubic meters of gas per 100 kilograms of oil.

A well located about 100 kilometers southeast of Boryslaw, at Bitkow, encountered a gas-bearing zone at a depth of 1,600 meters, which yielded gas in large quantities and had a reservoir pressure of 180 atmospheres. But the gas industry in the eastern district has not been developed because markets are inadequate. The quantity of gas produced in the district of Stanislawow in 1931 was about 48 million cubic meters.

POTOK DISTRICT

The first wells were drilled in 1912, but for several years the gas flowed freely to the atmosphere at rates of 200 cubic meters per minute per well. Thus, probably more than 1,000 million cubic meters were wasted. The initial pressure was not measured, but a recent completion at Roztoki had a pressure of about 100 atmospheres, flowing gas at the rate of about 200 cubic meters per minute.

TABLE I

PRODUCTION STATISTICS. PRODUCTION OF NATURAL GAS IN SADKOWA, DOBRUCOWA, BIALKOWKA, BRZEZOWKA, MECINKA, JASZCZEW, AND ROZTOKI FIELDS

Year	*Number of Wells*	*Cubic Meters*
1917	1	661,188
1918	1	10,800,831
1919	5	33,853,899
1920	5	95,326,611
1921	7	89,434,554
1922	11	85,297,351
1923	15	74,854,824
1924	16	63,532,785
1925	20	62,009,094
1926	24	57,399,610
1927	27	44,643,105
1928	26	44,982,316
1929	25	47,212,315
1930	22	50,475,027
1931	23	53,976,000
1932	23	54,426,000
		868,885,510

Table I shows the gas production from all fields on the Potok anticline from 1917 to 1932. The volume of gas wasted between 1912 and 1917 is not included. Eastern parts of the Potok anticline also yield oil. Krosno and Kroscienko are prolific oil-bearing areas. West-

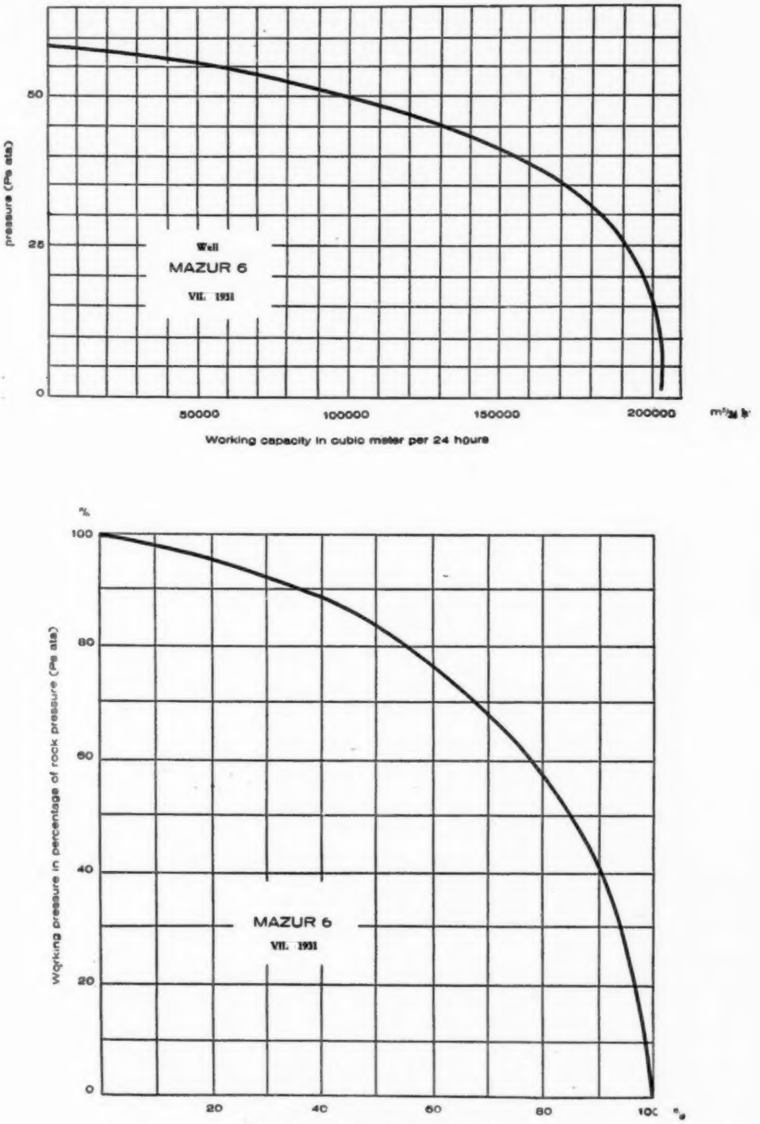

FIG. 6.—Chart showing working capacity of wells in Daszawa field.

ern parts of the gas-bearing area, especially in recent years, have begun to produce oil and rich gasoline vapors.

FORELAND (DASZAWA) BELT

The gas wells initially produced at the rate of 150–200 cubic meters per minute, and in recent time much more. The shut-in rock pressure was about 60 atmospheres.

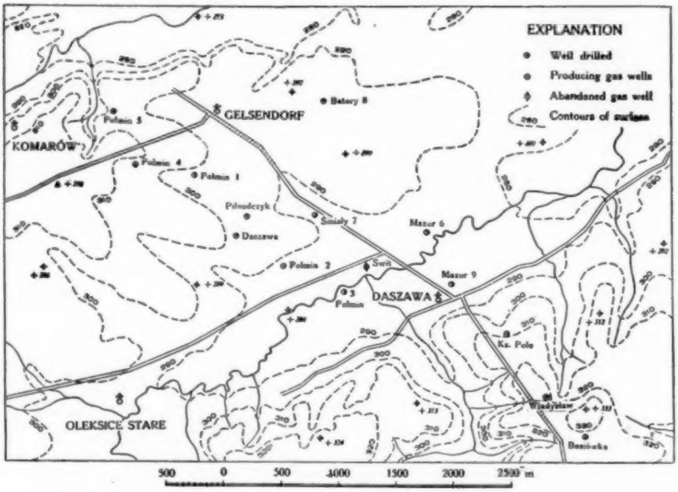

Fig. 7.—Map of Daszawa gas field, showing locations of wells.

The curves in Figure 6 give the working capacity of wells in the Daszawa field. Figure 7 shows the location of wells in the gas field.

Two gas pipe lines, from Daszawa to Stryj and Drohobycz (7-inch), are at present transporting about 200 cubic meters of gas per

TABLE II

Production of Natural Gas. Gas Fields of Daszawa District

Year	*Number of Wells*	*Cubic Meters*
1924	1	37,673,459
1925	2	45,549,626
1926	2	51,526,506
1927	3	51,894,371
1928	6	68,044,190
1929	8	88,211,727
1930	9	103,294,271
1931	10	109,188,855
1932	13	96,187,000
	Total	651,570,005

TABLE III

AVERAGE VALUE OF GAS ANALYSES IN BORYSLAW AND DASZAWA BY K. KATZ

Well	Locality	Company	Depth Meters	Time of Collecting	CO_2	O_2	H_2	CO	$C_nH_{2n}+2$	N_2	Total	Excess of CO_2 in Gas	Excess of CO_2 in $C_nH_{2n}+2$
BORYSLAW													
Zuzanna 1	Mraznica	B. Roth	1,479	21, IV, 1933	0.60	3.16	0	0	92.70	3.54	100.00	37.62	40.60
Zygmunt 4	Mraznica	Galicja	1,467	11, IV, 1933	0.63	4.24	0	0	88.66	6.47	100.00	35.32	39.84
DASZAWA													
Polmin 6	Daszawa	Polmin	317	13, VI, 1933	0.11	2.17	0	0	94.64	3.08	100.00	0	0
Basiowka	Daszawa	Gazolina	490	13, VI, 1933	0.06	2.02	0	0	95.19	2.73	100.00	0	0
Smialy	Daszawa	Gazolina	740	13, VI, 1933	0	2.33	0	0	94.23	3.44	100.00	1.50	1.59
Polmin 4	Daszawa	Polmin	775.6	13, VI, 1933	0.15	2.13	0	0	94.16	3.56	100.00	1.39	1.48

minute. The working pressure of these lines at Daszawa is about 10 atmospheres and the well-head pressure in the field is 30–50 atmospheres producing 20–30 cubic meters of gas per minute. Some of these wells have produced for 9 years.

Table II shows the production of the Daszawa gas field from 1924 to 1932. The waste of natural gas in this field has been slight, because the wells were shut in when completed.

UNDERGROUND WATERS

Intensive folding in the region complicates the underground water situation. One must distinguish waters in overthrust masses and in

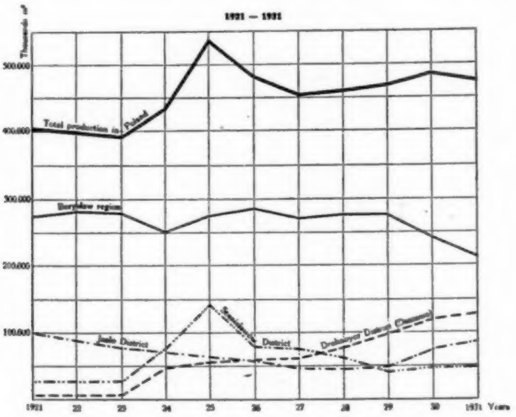

FIG. 8.—Chart showing statistics of production of natural gas in Poland, 1921–31.

the structurally low areas. In the latter, all the oil- and gas-producing horizons on the limb of the Boryslaw skiba are in contact with salt water. The hydrostatic pressure is approximately equivalent to the pressure at the base of a water column extending to 600 meters below sea-level. The Boryslaw sandstone, the Eocene and the Jamna sandstone are water-bearing in the southern dipping region. The Polanica beds on the southern limb are water-bearing in the syncline and in the southern dipping region. The constituents of these waters are similar, but by precise chemical analyses it is possible to establish certain differences in their composition, largely the proportion of *Cl* and SO_4.

In the Daszawa district large amounts of water are found above the chief gas-bearing horizons, but the chief gas-bearing horizon is free of water.

CONSUMPTION OF NATURAL GAS

Natural gas produced in Poland is utilized for two purposes, a source of natural gasoline and fuel. "Wet" and "dry" (Daszawa) gases are produced.

Statistics of natural gas produced in Poland since 1916 are available (Table IV and Figure 8).

TABLE IV

PRODUCTION OF NATURAL GAS IN POLAND, 1916–1932
(Thousands of cubic meters)

Year	*Boryslaw*	*District of Drohobycz with Exception Boryslaw*	*District of Jaslo*	*District of Stanislawow*	*Total*
1916	352,000				352,000
1917	347,000				347,000
1918	336,000				336,000
1919	285,000	486	7,593	3,749	296,828
1920	282,000	3,810	172,420	9,090	467,320
1921	274,000	4,900	100,074	25,436	404,489
1922	283,000	5,000	88,000	26,000	402,685
1923	280,000	6,149	77,052	26,850	390,051
1924	250,000	47,335	70,000	75,114	442,845
1925	276,000	55,084	63,740	142,258	537,082
1926	285,612	59,067	57,946	78,697	481,322
1927	271,213	60,733	45,537	76,117	453,600
1928	277,232	76,083	44,054	62,162	459,531
1929	276,235	99,306	49,135	42,007	466,683
1930	242,612	120,034	75,432	48,428	486,506
1931	211,763	127,549	86,719	47,792	473,823
1932	186,764	115,811	86,347	48,008	436,930
Total	4,716,431	781,347	1,024,049	711,708	7,234,695

These statistics indicate that the largest quantity of natural gas so far produced has been from Boryslaw, 4,716,431,000 cubic meters, and that the remainder has come from minor wells, in the districts of Drohobycz, Jaslo, and Stanislawow. The total gas production, according to statistics, in the period 1916 to 1932, is more than 7,234,695,000 cubic meters. Inclusive of the quantity of gas wasted in the first years of exploitation, it is estimated that the quantity of natural gas produced in the oil and gas fields of Poland amounts to at least 12,000 million cubic meters.

"Dry" gas from the Daszawa fields is used only for fuel. This gas is transported by pipe lines to the refinery at Drohobycz, to Boryslaw, and recently to Lwow, a distance of about 150 kilometers.

In the Western Carpathian region, pipe lines convey gas short distances for oil field fuel use only. In 1932 a new pipe line (10-inch) was constructed from Jaslo to Tarnow and Moseice (77 kilometers).

TABLE V

NATURAL GASOLINE PRODUCED IN POLAND 1926–1932

(Kilograms)

Year	*District Jaslo*		*District Drohobycz*		*District Stanislawow*		*Total*	
	Natural Gas Treated Cubic Meters	*Produced Gasoline Kilograms*	*Natural Gas Treated Cubic Meters*	*Produced Gasoline Kilograms*	*Natural Gas Treated Cubic Meters*	*Produced Gasoline Kilograms*	*Natural Gas Treated Cubic Meters*	*Produced Gasoline Kilograms*
1926			156,999,563	17,149,844	29,140,941	894,331	186,140,504	18,044,175
1927			219,848,444	25,287,961	28,546,391	2,496,192	248,394,835	27,784,153
1928			228,179,905	28,931,005	31,025,325	2,923,935	259,205,230	31,854,940
1929			247,014,636	31,586,974	30,068,121	2,917,502	277,082,757	34,504,476
1930	798,150	197,240	249,897,875	34,903,905	35,355,112	3,392,505	286,051,137	38,493,650
1931	7,578,165	1,455,932	232,794,151	36,140,120	37,253,363	3,384,970	277,625,679	40,981,022
1932	17,893,988	2,521,915	199,009,902	33,257,716	34,298,243	3,053,045	251,202,133	38,832,676
Total	26,270,303	4,175,087	1,533,744,476	207,257,525	225,687,496	19,062,480	1,785,702,275	230,495,092

PRODUCTION OF NATURAL GASOLINE

Table V shows the quantity of natural gas treated and the production of gasoline in the period 1926–32. The natural gasoline industry in Poland has grown steadily, and the quantity of gasoline recovered per cubic meter has increased.

There were 23 operating natural gasoline extraction plants in Poland in January, 1932, which treated 22,513,725 cubic meters of natural gas and 3,631,793 kilograms of gasoline. The gas is treated in plants using the absorption and compression methods.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 908-924, 3 FIGS.

PETROLEUM RESOURCES OF JAPAN[1]

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ABSTRACT

A petroleum belt extends from southern Saghalien and Hokkaidō to Nagano Prefecture in Honshū Island, along the coast of the Japan Sea. Besides, there are small fields of Shizuoka Prefecture in Honshū and the Island of Taiwan (Formosa). Petroleum deposits in Japan are found exclusively in marine Neogene formations. The chief oil fields in Hokkaidō are those of Masuhoro, Ishikari, and Yufutsu, of which Yufutsu is the most important. In the Prefecture of Akita, the oil fields of Kurokawa, Toyokawa, Michikawa-Asahigawa, and Oguni are noteworthy, though at present their aggregate production amounts to only about 108,000 kiloliters a year. The oil fields of Niitsu, Nishiyama, and Higashiyama in Niigata Prefecture have been worked since about 39 years ago and their total production together with that of minor fields in the vicinities amounted to about 360,000 kiloliters in 1914. Since then the production gradually diminished and was only about 192,000 kiloliters in 1930. In Taiwan, the only field which is now productive is that of Byoritsu. Others are expected to be developed in the future.

GEOGRAPHIC DISTRIBUTION

The main petroleum belt of Japan extends from southern Saghalien and Hokkaidō on the north to Nagano Prefecture, Honshū, on the south, along the coast of the Japan Sea. Besides, there are small fields of oil in Shizuoka Prefecture, Honshū, as well as on the Island of Formosa. In southern Saghalien the oil-bearing strata occur in the western part of the island. In Hokkaidō they extend from north to south on the west side of the central mountain range. In Honshū they begin in Aomori Prefecture and continue to the western part of the prefectures of Akita and Yamagata, and then to that of Niigata whence they extend to the northern part of Nagano Prefecture. An isolated district is also found on the Pacific coast of Honshū, namely, in Shizuoka Prefecture. In Formosa (Taiwan) there is an oil belt extending from north to south in its western part, that is, in the Byōritsu district, Shinchiku Prefecture. This seems to be the most important one in the island at present.

[1] Read by title before the Section on the Geology of Petroleum, of the 16th International Geological Congress, at Washington, D. C., July, 1933. Manuscript received, December 2, 1933.

[2] Geologist, Imperial Geological Survey of Japan. Introduced by W. C. Mendenhall.

OIL FIELDS OF HOKKAIDŌ

In Hokkaidō there is an oil belt extending from north to south on the west side of the central mountain chain, passing through the provinces of Kitami, Teshio, Ishikari, Iburi, and Hidaka.

The Neogene formation is here divided as shown in Table I.

TABLE I

		Geological Division	*Principal Rocks*	*Oil Horizons*	*Thickness in Meters*
Pliocene	Oiwake Series	Kuriyama beds	Sandstone and conglomerate		300–400
		Oiwake beds	Sandy shale		1,100
		Wakkanai beds	Siliceous shale Sandstone	x	1,200
Miocene	Horonai Series Kawabata Series		Black shale with sandstone	x	
		Kawabata beds (Masuhoro beds)	Sandstone, conglomerate, and shale	x	4,400
		Poronai beds	Black clayey shale		900

FIG. 1

TABLE II

Names of Oil Fields	Names of Districts	Principal Anticlinal Fold				Geological Horizon of Main Oil Sand	Depth of Oil Wells Meters	Baumé Gravity of Oil
		General Direction	Length Meters	Width Meters	Inclination			
Ishikari	Ishikari	NNE.–SSW.	6,000	500–1,000	20°–30°	Wakkanai beds	500–600	42°
Yufutsu (1) Fureoi	Yufutsu	NNW.–SSE.	4,000	200– 300	20°–30°	Wakkanai beds		30°
(2) Karumai	Yufutsu	NW.–SE.	4,000	200– 400	15°–30°	Wakkanai beds	140–650	32°
Masuhoro	Sōya	NNW.–SSE.	6,000	100– 200	20°–30°	Kawabata beds	200–380	27°–30°

TABLE III

	Ishikari		Yufutsu		Masuhoro		Total
Year	Quantity in Kiloliters A	Number of Oil Wells B	A	B	A	B	
1927	7,658.10	60	2,782.34	53	652.83	10	11,093.27
1928	9,506.73	82	2,785.58	60	2,536.10	10	14,828.41
1929	9,980.08	106	4,403.32	81	804.36	12	15,187.76
1930	9,680.20	131	5,556.30	108	366.73	9	15,603.23
1931	9,132.90	153	9,105.20	137	316.40	6	18,554.50

The fields which actually produce oil are three: Masuhoro, Ishikari, and Yufutsu.

The Ishikari field is situated in a hilly tract about 8 kilometers northeast of the town of Ishikari. The work of getting oil was begun as early as 1887, but its progress was so slow that one-third of the field still remains untouched. The strata composing the field form a broad domal anticline sloping toward the south. The main oil-bearing bed is a fine sandstone which belongs the Wakkanai beds, and lies at the depth of 500–600 meters; another oil sand is only 200 meters deep. The initial production was small, amounting on an average to 7–9 kiloliters a day. At present there are about 150 productive wells with an average daily production of 22 kiloliters altogether. The Yufutsu oil field lies in a hilly region about 12 kilometers northeast of the railway station of Hayakita. It was first drilled in 1891, then yielding only a small amount of oil. In 1924, however, more oil was found at a depth of about 83 meters. Since then many wells were drilled with success so that in 1931 the production increased considerably. The oil sand occurs within a gray shale in the lower part of the Wakkanai beds. There are two such, the upper lying 66–180 meters in depth and the lower 500–700 meters in depth. The geological features of the oil fields of Hokkaidō are shown in Table II.

In the Hokkaidō oil fields there are many districts which are still untouched, such as those of Wakkanai-machi in Sōya-gun, Horonobu and Teshio-machi in Teshio-gun, Iwamizawa in Sorachi-gun, and Fureoi and Mukawa in Yufutsu-gun.

The production of the Hokkaidō oil fields during the latest 5 years is shown in Table III.

OIL FIELDS OF AKITA

In the Prefecture of Akita, the oil belt extends from north to south along the coast, including the districts of Yamamoto, K. Akita, M. Akita, and Yuri. It is about 30–50 kilometers in breadth and about 170 kilometers in length.

The Neogene formation found in the oil fields is divided as shown in Table IV.

The districts which yield oil are six: Hibiki, Toyokawa, Kurokawa, Michikawa-Asahigawa, Oguni, and Yuri, of which the last is made up of six minor ones of Katsurane, Hanekawa, Katte, Uchimichikawa, and Tanaka.

The development of the fields in Akita was undertaken at a much later date than in Niigata. The first trial well was drilled with cable tools in 1902 at Izumi in the oil field of Asahigawa and also at Toyo-

TABLE IV

	Geological Division		*Principal Rocks*	*Thickness Meters*	*Oil Horizon*
Pliocene	Takanosu series	Bōzawa beds	Sand, gravel and clay	200–250	
		Shibikawa beds	Sandstone		
	Yuri series	Wakimoto beds	Sandy shale	200–500	x
		Kitaura beds	Alternations of sandstone and shale or gray shale	200–600	x
Miocene	Ogashima series	Funagawa beds	Black shale with sandstone and tuff	400–900	x
		Onagawa beds	Siliceous shale with marl, sandstone and tuff	250–600	x
	Innai series	Sugoroku beds	Green tuff with conglomerate and sandstone		

maki in the Yuri field. But the work went on rather slowly until 1914, when in the Kurokawa oil field there appeared a well suddenly pouring out a great quantity of oil whose initial daily production exceeded 1,800 kiloliters. Since then the neighboring fields of Toyokawa, Michikawa, and Asahigawa were carefully exploited and subsequently found to be also very productive. The Yuri fields have been worked since 1921 and are yielding much oil. The annual production of all the Akita oil fields exceeded 180,000 kiloliters in 1921, but since then it gradually declined and was bout 108,000 kiloliters in 1930.

The Toyokawa field is in a hilly district 30–50 meters above the level of the sea and 2 kilometers east of the Ōkubo Station on the Ōu Railway. It consists of the shale of the Funagawa beds, forming a broad anticline which is disturbed by several small faults. The producing field occupies an area 4,000 meters in length and 800–1,000 meters in width. The chief reservoir of oil is found in a fractured zone in the lower part of the Funagawa beds and lies 230–400 meters below sea-level. There are also oil-bearing tufaceous sands within the same beds. The oil has a gravity of 20°–22° Bé. During the most productive period there were many wells yielding 35–55 kiloliters a day, but at present the total production is only 55–77 kiloliters a day.

The Kurokawa field lies in a hilly tract 12 kilometers north of the city of Akita. The strata consist of shale belonging to the Funagawa beds. The structure is a typical domal anticline with an axis extending

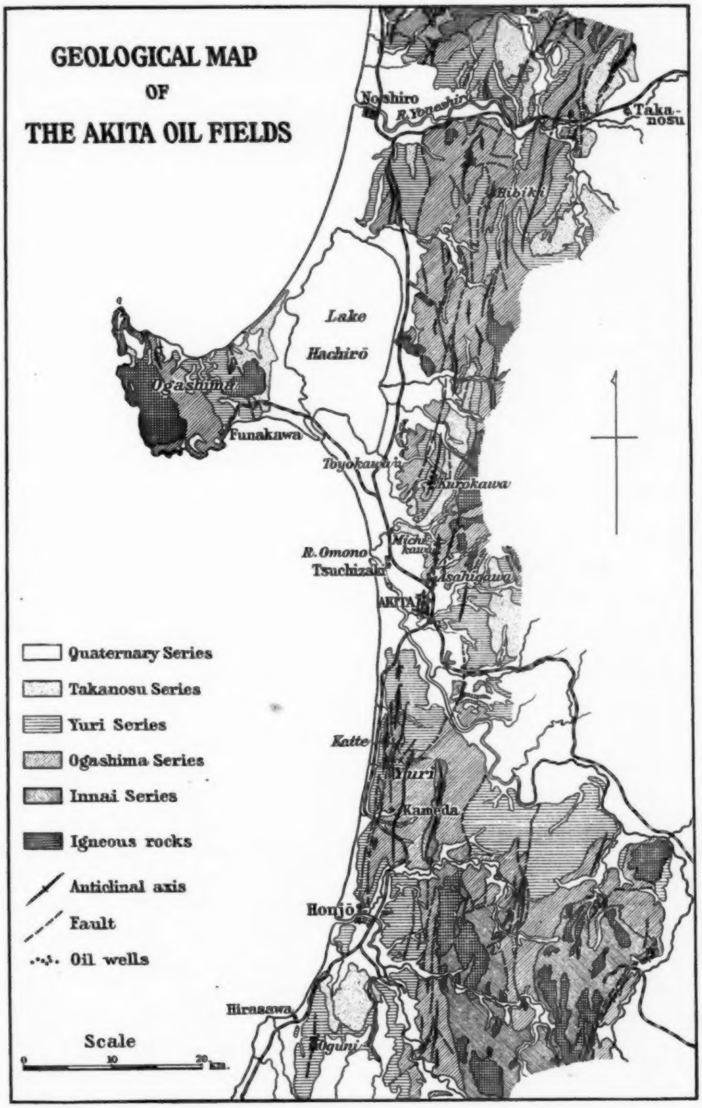
GEOLOGICAL MAP
OF
THE AKITA OIL FIELDS
Noshiro
R. Yoneshiro
Takanosu
Hibiki
Lake
Hachirō
Ogashima
Funakawa
Toyokawa
Kurokawa
Michikawa
R. Omono
Tsuchizaki
Asahigawa
AKITA
Katte
Yuri
Kameda
Honjō
Hirasawa
Koguni
Quaternary Series
Takanosu Series
Yuri Series
Ogashima Series
Innai Series
Igneous rocks
Anticlinal axis
Fault
Oil wells
Scale
0
10
20 km.

FIG 2

north and south. The average dip is 20° on both flanks. The productive field occupies an area 3,500 meters in length and 400–900 meters in width. The chief oil reservoir is found in the fractured zone of the transitional part between the Funagawa and Onagawa beds as well as in the sands found in the lower part of the Funagawa beds and the upper part of the Onagawa beds. Some shallow oil is also found in the fissures of shale. The chief oil-bearing zone lies 400–480 meters below the surface. For 6 or 7 years following 1914, this field was the center of the oil industry and there were gushers producing several hundred kiloliters a day. Since then the production gradually diminished and at present it is only 45–50 kiloliters a day.

The Michikawa-Asahigawa field lies in a hilly tract as well as in a flat terrane along Asahigawa River 4–8 kilometers north of the city of Akita. The strata consist of shale belonging to the Funagawa beds.

In the Michikawa field drilling was commenced in 1908, and in 1918 a productive oil zone was reached at the depth of about 150 meters. The big gusher No. 29 was completed in 1920 and yielded about 1,800 kiloliters of oil in a day. In this year the whole production was 22,000 kiloliters. The oil is of a low grade, having a gravity of about 13° or 14° Bé. The production is gradually diminishing.

In 1908 the Nigorigawa field which lies in a hilly region between those of Michikawa and Asahigawa was drilled by means of the Kazusa system, but without success. In 1921 a productive oil zone was struck at the depth of 100 meters which yielded about 50–100 kiloliters of oil daily. The oil is of a rather low grade, having a gravity of about 21° Bé.

Between 1866 and 1901 some wells were drilled in the Asahigawa field on the Kazusa system as well as by hand digging, the latter of which succeeded in getting two wells yielding a few barrels of oil daily at the depth of 127 meters.

In 1908 a well drilled by the cable-tool method yielded about 10 barrels of oil daily at the depth of 110 meters.

In 1914 the well No. 79 yielded about 20 barrels daily at the depth of 330 meters considered to be a new oil zone at that time. Since then many wells have been sunk to depths below 600 meters. The oil is of a rather low grade, having a gravity of 18°–24° Bé.

The Yuri field, in the northern part of Yuri-gun, Akita Prefecture, has five subfields: Katsurane, Hanekawa, Katte, Uchimichikawa, and Tanaka, which altogether produce only 70 kiloliters a day.

The Katte subfield was first opened in 1921 and is now the most productive in the Yuri district except that of Oguni. In the Oguni field, found in the southern region of Yuri-gun, the drilling was under-

TABLE V

Oil Fields	District	Principal Anticlinal Folds: General Direction	Length Meters	Width Meters	Inclination	Geological Horizon of Main Oil Sand	Depth of Oil Wells Meters	Baumé Gravity of Oil
Hibiki	Yamamoto	N–S	2,000	200–300	30°–40°	Lower Funagawa beds	200–250	12°–13°
Toyokawa	Minami Akita	N–S	4,000	800–1,000	Gentle	Lower Funagawa beds	250–600	20°–22°
Kurokawa	Minami Akita	N–S	3,500	400–900	20°	Lower Funagawa beds	400–480	18°–19°
Michikawa-Asahigawa	Minami Akita	N–S	3,500	250–600	20°–30°	Funagawa beds	150–600	13°–24°
Yuri								
(1) Katsurane	Yuri	N–S	2,000	500	20°–30°	Kitaura beds, Funagawa beds	200–770	25°–40°
(2) Kanekawa	Yuri	N–S	5,000	300	45°–50°	Funagawa beds	100–400	31°
(3) Katte	Yuri	N–S	3,500	300	40°–65°	Funagawa beds	150–650	30°–39°
(4) Uchimichikawa	Yuri	N–S	1,500	300	20°–30°	Kitaura beds, Funagawa beds	60–150	32°–35°
(5) Tanaka	Yuri	NNE.–SSW.	10,000	200	40°–70°	Onagawa beds	100–200	30°
Oguni	Yuri	N–S	7,500	200–300	30°–70°	Kitaura beds, Funagawa beds	110–400	30°–35°

TABLE VI

Year	Kurokawa: Quantity in Kiloliters A	Kurokawa: No. of Oil wells B	Toyokawa A	Toyokawa B	Michikawa (Including Nigorikawa) A	Michikawa (Including Nigorikawa) B	Asahigawa A	Asahigawa B	Yuri A	Yuri B	Oguni A	Oguni B
1927	25,420.38	232	32,328.77	541	30,055.32	272	9,457.85	77	17,444.98	281	5,612.47	32
1928	21,928.75	231	32,306.05	587	17,639.44	182	13,648.85	138	17,184.67	284	6,351.17	37
1929	18,843.36	228	25,814.17	585	17,095.56	181	19,852.64	145	15,767.17	281	10,335.81	41
1930	16,719.10	225	23,086.49	571	17,332.60	196	18,242.50	157	14,107.60	280	13,241.70	43
1931	14,940.00	223	17,842.60	484	15,942.27	174	16,367.10	124	11,480.00	267	12,285.70	48

taken as early as 1893, but it was not active until 1922. At present there are about 50 wells which altogether produce about 40 kiloliters a day.

Table V shows geological data of the Akita oil fields.

In the Akita oil field there are many districts which are still undeveloped, of which those lying at the northern and southern extremities seem to be promising.

The production of the field during the latest 5 years was as follows.

Year	*Kiloliters*
1926	121,074.16
1927	113,342.29
1928	110,874.91
1929	111,450.50
1930	108,057.70

OIL FIELDS OF NIIGATA

The oil fields of Niigata Prefecture occupy almost the central part of Honshū, along the coast of the Sea of Japan. The oil belt extends from northeast to southwest for a distance of about 200 kilometers and ranges from 20 to 40 kilometers in breadth.

In this prefecture the use of crude petroleum as a fuel is very old. It can be traced back to a period more than 300 years ago. Before 1893 all wells were either dug by hand or drilled by a simple method called "Kazusa-bori." In 1893, the American method of cable-tool drilling was applied for the first time at Nishiyama with success, after which the oil industry has been improved greatly and several fields have been developed one after another. In 1912, the rotary system of boring was

TABLE VII

	Geological Division		*Principal Rocks*	*Thickness Meters*	*Oil Horizon*
Pliocene	Uonuma series	Tsukayama beds	Sandstone with gravel	900	
		Wanazu sand	Sand and shale	100–600	
	Chūetsu series	Nishiyama beds	Sandy shale	300–600	x
		Shiiya beds	Alternations of sandstone and shale or gray shale	200–600	x
Miocene	Kubiki series	Kubiki beds	Black shale with sandstone and tuff	1,700	x
	Tsugawa series	Tsugawa beds	(Siliceous shale) Green tuff with sandstone, conglomerate		

tried with success at Imo in the Nishiyama oil field, and since then it has been used in the oil fields together with the cable-tool method.

As a consequence of the application of the cable and rotary systems, the production of oil was greatly increased, especially in the Niitsu oil field, and in 1914 it reached approximately 300,000 kilo-

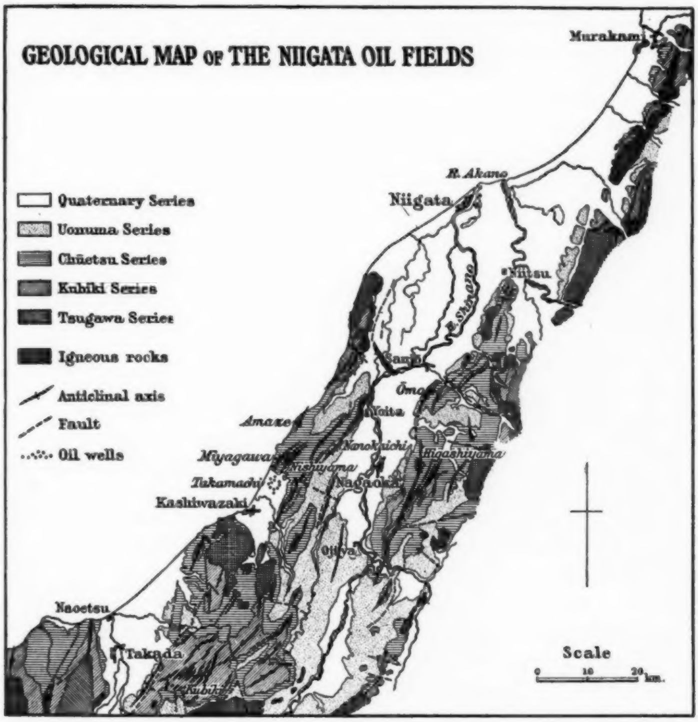

FIG. 3

liters. Subsequently, however, it gradually decreased and in 1931 it was only about 111,000 kiloliters.

The Neogene formation in the oil fields is classified as shown in Table VII.

In the Prefecture of Niigata, there are six districts producing oil; Niitsu, Ōmo, Higashiyama, Nanokaichi, Nishiyama (including Takamachi), and Kubiki. The following description relates only to the important districts.

Niitsu field.—This field lies near the town of Niitsu, 20 kilometers south of the city of Niigata. It is a low hilly tract extending about 6 kilometers from north to south, and ranging in breadth from 1,000 to 2,000 meters. The strata seem to form a broad anticline with the axis extending northeast and southwest. Oil sands occur in several different horizons, lying at depths between 160 and 500 meters below the ground surface. The main oil sand interbedded in the Kanazu sands is the most important source of oil. It is found almost everywhere in the field, occupying an area of more than 134 hectares. Its total thickness varies between 10 and 40 meters, separated into two or three layers by intervening shales. The principal oil accumulations are found at the swollen portions of the anticline, while the intervening troughs are generally less productive. The Koguchi swell is the largest and most productive in the field, showing a gentle inclination on both sides.

Deep test wells of about 900–1,000 meters or more at Umayose, Higashijima, and Mayedani have shown the presence of the deep oil sands accompanied by a considerable amount of gas, so that these districts are promising for the future.

Nishiyama fields.—Under this head are included the four oil fields of Amaze, Miyagawa, Nishiyama Proper, and Takamachi, of which the last is a newly developed field south of Nishiyama Proper.

The oil fields of Nishiyama Proper, situated near the Nishiyama Railway station 12 kilometers northeast of the town of Kashiwazáki, consist of a sandy shale belonging to the Nishiyama beds which overlie the alternations of sandstone and shale of the Shiiya beds and black shale of the Kubiki beds. The oil sand of the field may be divided into four zones.

The first oil zone lies at a depth between 170 and 300 meters below the ground surface and consists of several layers of oil sands. The greater part of this zone was drilled before 1910 and the oil is of an inferior quality, having a Baumé gravity varying from 23° to 29°.

The second oil zone is at a depth between 300 and 460 meters and is mostly encountered at Nagamine where it consists of several layers of oil sands.

The third oil zone is at a depth between 460 and 760 meters below the surface and consists of many subzones. This zone extends over almost the entire field and is most productive in its northern and southern quarters, while its central part, Nagamine and Kamata, is characterized by the production of gas with less oil. The oil is usually of a high grade, being more than 40° Bé.

The fourth oil zone is deeper than 900 meters from the surface of

the ground at Nagamine, where the deepest well is about 1,090 meters, penetrating several productive oil sands containing much gas. In the northern and southern quarters of the field these sands lie at depths ranging from 1,220 to 1,280 meters below the surface. The produced oil has a gravity of 46° Bé.

The Takamachi field is in an alluvial plain as well as among sand dunes 6 kilometers northeast of the town of Kashiwazaki, and embraces an area about 4 kilometers in length and 600–1,000 meters in width. The strata below the alluvial deposit consist of the sandy shale of the Nishiyama beds, the alternations of sandstone and shale of the Shiiya beds, and the black shale of the Kubiki beds. They seem to form a gentle anticline with oil sands occurring in the Shiiya and Kubiki beds. The field was opened in 1924 and during the first 3 years a large amount of gas was obtained with a small quantity of oil at depths ranging from 800 to 1,000 meters. In 1927 a rotary well drilled at Warimachi in the northern part of the field reached to the depth of 830 meters, whence much gas was obtained amounting to about 200,000 cubic meters a day. But owing to the gradual decrease of the production, deeper drilling was tried, and in January, 1928, a very productive oil zone was discovered at the depth of 1,132–1,142 meters. The well produced 30 kiloliters of oil daily. After this, another gusher, Takamachi No. 8, was completed, which produced about 56 kiloliters daily at the depth of 1,400 meters. Since that time the field has been greatly developed and now there are about 160 productive wells.

The production of the Takamachi field during the latest 5 years is shown in Table VIII.

TABLE VIII

	Takamachi (Nihon Oil Co.)			*Takamachi (Nakano Co.)*		
Year	*Petroleum (in Kiloliters)* A	*Natural Gas (in Thousand Cubic Meters)* B	*Number of Oil Wells* C	*A*	*B*	*C*
1927	155.61	9,377,943	3	—	—	—
1928	30,905.39	10,496,076	24	2,185.06	362,432	4
1929	41,754.32	8,588,663	55	21,647.16	8,218,429	24
1930	36,243.95	9,292,393	78	42,886.82	17,991,351	51
1931	44,659.21	6,866,292	89	44,429.89	—	63

Kubiki field.—This field, 12 kilometers southeast of the city of Takada, embraces the oil districts scattered along Iida River. The

TABLE IX

Oil Field	District	Principal Anticlinal Folds				Geological Horizon of Oil Sand	Depth of Oil Wells Meters	Baumé Gravity of Oil	
		General Direction	Length Meters	Width Meters	Inclination				
Niitsu........	Nakakambara	NE.-SW.	6,000	1,000-2,000	Gentle	Sandy shale, Kanazu sand, and Kubiki beds	160-730	17.5°-22°	
Ōmo.........	Minami Kambara	NE.-SW.	6,000	300-600	30°-70°	Gray sandy shale of Shiiya series	800-900	23°	
Nanokaichi...	Santō	NE.-SW.	5,000	500-600	15°-50° on east limb; 10°-20° on west limb	Sandy shale	220-232	19.3°	
Higashiyama.	Koshi	N-S	4,000	800	10°-50°	Kubiki beds	20-300	23°-32°	
Nishiyama									
(1) Amaze..	Santō	NE.-SW.	5,000	400	30°	Kubiki beds	360-640	38°-42°	
(2) Miyagawa......	Kariha	NE.-SW.	4,000	300-450	20°-30°	Kubiki beds	360-570	32°-47.5°	Yield comparatively small
(3) The Nishiyama Proper...	Kariha	NE.-SW.	7,000	300-600	20°-30°	Shiiya beds Kubiki beds	170-1,280	46°	
(4) Takamachi....	Kariha	NE.-SW.	4,000	600-1,000	—	Shiiya and Kubiki beds	1,100-1,400		
Kubiki.......	Higashi-Kubiki	NE.-SW.	Many producing properties included in 16 square kilometers			Kubiki beds	180-280	40°-45°	

TABLE X

Year	Higashiyama		Omo		Niitsu		Nishiyama		Nanokaichi		Kubiki	
	Quantity Kiloliters A	No. of Oil wells B	A	B	A	B	A	B	A	B	A	B
1927	14,596.98	675	12,433.74	25	59,192.81	1,316	44,975.56	456	2,270.03	138	1,748.70	297
1928	14,193.99	652	16,794.49	37	55,332.11	1,312	73,633.39	473	1,958.13	129	1,727.41	292
1929	13,671.76	633	17,778.34	47	51,850.58	1,279	95,878.91	515	1,823.20	118	1,697.44	288
1930	13,094.90	615	18,117.70	57	48,803.20	1,233	100,230.40	555	1,584.39	100	1,617.17	287
1931	12,802.30	597	14,734.60	63	47,477.50	1,238	111,416.20	563	1,257.10	93	1,552.50	287

strata found here chiefly consist of black shale of the Kubiki beds. Thick tuff layers locally known as "Shiro" are interbedded in the shale and form the important source of oil. In the Iwagami district, which was once an important center of the oil industry, there is a gentle dome-like structure; but farther south the strata, so far as known, are homoclinal with a dip of 20° accompanied by several faults and flexures which greatly influence the accumulation of oil. Here the depths of wells vary from 180 to 250 meters and the oil obtained is of the best quality in Japan, having a gravity of 40°–45° Bé and containing some paraffine.

The geological characteristics of the Niigata oil fields are shown in Table IX.

In the Niigata oil fields there are many places which are promising though not yet prospected, the most important being Kamo-machi, the eastern part of the Higashiyama oil field, the southeastern part of Kariha-gun, and several places in Higashi and Naka Kubiki-gun.

The production in all the fields is as follows.

Year	*Kiloliters*
1926	140,486.47
1927	136,804.89
1928	166,464.79
1929	184,599.80
1930	191,746.30

OIL FIELDS OF TAIWAN

In Taiwan (Formosa) an oil belt extends from north to south for a distance of about 350 kilometers in the western part of the island.

The Tertiary formation in the oil fields is divided as shown in Table XI.

TABLE XI

Series	*Beds*	*Principal Rocks*	*Oil Horizon*	*Thickness Meters*
Shinchiku series	Shokkozan beds	Loose sand and gravel		750–1,900
	Byōritsu beds	Sandstone, sandy shale		2,000–4,100
Taihoku series	Arizan beds	Sandstone, shale	x	1,500–5,000
	Karisan beds	Gray sandstone, slate, shale		1,000–2,000

There are two important fields, Shikkokō and Kinsui, the latter having been developed as a gas field since 1924.

The Shikkokō field lies in a mountain region about 12 kilometers

southeast of the town of Byōritsu, in the Prefecture of Shinchiku. It began to be developed in 1904, but was not productive until 1926. The strata form an anticline about 27 kilometers in length, dipping 40°–70° on the east limb and 35°–60° on the west limb, while in the southern part of the productive area they dip 20° on the west limb. The strata consist of alternations of calcareous sandstone and shale of the Arisan beds. The area in which oil was proved to exist is about 5.5 kilometers in length and 300–350 meters in width. At depths varying between 223 and 955 meters six oil sands have been found, of which those lying deeper than 750 meters are very productive. The oil has a gravity of 29° Bé.

The production of the field during the last 5 years was as follows.

Year	*Quantity (Kiloliters)*	*Number of Oil Wells*
1927	22,827.03	22
1928	18,029.40	29
1929	12,673.67	33
1930	8,863.14	37
1931	6,810.93	29

The Kinsui gas field lies in a hilly region about 8 kilometers northeast of the town of Byōritsu. The strata consist of sandstone and sandy shale belonging to the Byōritsu beds, and form an anticline extending northeast and southwest about 20 kilometers and dipping 10°–40° on both limbs. Gas reservoirs containing gasoline are found in a sandstone which belongs to the Arisan beds and lies at depths of 500–850 meters from the surface. The gas produced from underground was at first used for extracting gasoline and subsequently also for making carbon-black, the residual gas being burnt as a fuel.

The production of natural gas and gasoline in the Kinsui field is as follows.

Year	*Natural Gas (in Thousand Cubic Meters)*	*Gasoline (in Kiloliters)*	*Number of Wells*
1927	2,465,517	473.55	1
1928	3,635,350	491.50	1
1929	3,897,482	1,505.45	1
1930	4,681,216	6,964.68	2
1931	322,541,329	18,614.32	2

In Taiwan there are several districts which are to be developed in the future.

PROSPECTIVE OIL FIELDS

Besides the oil fields already discovered, there are many promising fields at Hokkaidō, Aomori, Akita, Yamagata, Niigata, Nagano,

Shizuoka, and Taiwan. Since 1927, thirty-six wells have been drilled in the search for oil in fields that were favored by subsidies from the Government by individuals as well as by oil companies.

The result of this drilling is shown in Table XII.

TABLE XII

	Village	*Districts*	*Prefecture*	*Number of Wells*	*Depth of Wells*	*Remarks*
1	Horonobu...	Teshio	Hokkaidō	1	1,100	Abandoned
2	Atsuma.....	Yōfutsu	Kokkaidō	1	1,100	Abandoned
3	Niikappu....	Niikappu	Hokkaidō	2	1,000	Abandoned
4	Atsuta......	Ishikari	Kokkaidō	2	1,100	Abandoned
5	Mukawa....	Yōfutsu	Kokkaidō	1		Drilling
6	Wakkanai...	Sōya	Kokkaidō	1	1,400	Abandoned
7	Shinjo......	Higashi-tsugaru	Aomori	1	1,100	Abandoned
8	Tokiwa.....	Yamamoto	Akita	1	1,000	Abandoned
9	Hibiki......	Yamamoto	Akita	1	640	Abandoned
10	Oganaka....	Minami-akita	Akita	1	1,135	Abandoned
11	Shimokitade	Kawabe	Akita	1	1,100	Abandoned
12	Michikawa..	Yuri	Akita	1	800	Abandoned
13	Kamikidate..	Kawabe	Akita	1	1,100	Abandoned
14	Shimohama..	Yuri	Akita	1	1,200	Abandoned
15	Innai.......	Yuri	Akita	1	619	Yielded 20 koku per day
16	Iriai........	Minami-akita	Akita	1	187	Oil 29° Bé. yielded 40 koku per day for about two weeks
17	Iidagawa....	Minami-akita	Akita	1	900	Abandoned
18	Yashima....	Yuri	Akita	1	786	Abandoned
19	Matsugasaki	Yuri	Akita	1	800	Abandoned
20	Ōkura......	Mogami	Yamagata	1	1,000	Abandoned
21	Tozawa	Mogami	Yamagata	1		Drilling
22	Gejō........	Minami-kambara	Niigata	1	1,364	Abandoned
23	Ōmo........	Minami-kambara	Niigata	1	1,002	Abandoned
24	Awazu......	Nishi-kambara	Niigata	2	1,100	Abandoned
25	Nishikoshi...	Santō	Niigata	1	800	Abandoned
26	Yoita.......	Santō	Niigata	1	814	Abandoned on encountering caving strata
27	Miyamoto...	Santō	Niigata	2	1,100	Abandoned
28	Kitajō......	Kariha	Niigata	1	1,163	Abandoned
29	Takeishi.....	Kariha	Niigata	1	336	Abandoned on encountering caving strata
30	Takayanagi	Kariha	Niigata	1	1,200	Abandoned
31	Tajiri.......	Kariha	Niigata	1	1,509	Abandoned
32	Shirokawa...	Kita-uonuma	Niigata	1	1,800	Abandoned
33	Ōtsu........	Santō	Niigata	1	1,209	Abandoned
34	Mitsuke.....	Minami-kambara	Niigata	1	1,809	Abandoned
35	Imamachi...	Minami-kambara	Niigata	1		Drilling
36	Nanaki.....	Kita-azumi	Nagano	1	600	Abandoned

PRODUCTION AND IMPORTATION OF CRUDE PETROLEUM

According to the statistics furnished by the Department of Industry and Commerce, the production and importation of crude oil in Japan during the latest 5 years were as shown in Table XIII.

TABLE XIII

PRODUCTION

Year	*Quantity in Kiloliters*	*Value in Yen*
1926	269,950.40	14,971,914
1927	261,545.40	12,466,489
1928	292,251.70	12,945,601
1929	311,339.90	13,707,355
1930	316,560.20	14,272,461
	IMPORT	
Year	*Quantity in Kiloliters*	*Value in Yen*
1926	446,824.34	19,235,074
1927	616,467.00	23,992,884
1928	1,442,682.07	45,162,680
1929	1,591,104.54	46,603,450
1930	1,615,960.11	44,775,518

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 925-941, 2 FIGS.

TECTONICS AND PALEOGEOGRAPHY OF BASIN SYSTEM OF HUNGARY ELUCIDATED BY DRILLING FOR OIL[1]

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ABSTRACT

Geological data from one of the 9 deep test holes drilled in the Big Hungarian Plain by the Hungarian State indicate that the basement rocks of semicrystalline limestone, dolomite, and marl lie at a depth of 1,619 meters (5,310 feet) and they may be early Paleozoic in age. The overlying beds are Oligocene, Miocene, and Pliocene in age. The Pannonian Pliocene strata especially are thick and seem to be much folded and faulted. Strong showings of gas and bitumen in these formations probably indicate the presence of deeper source rocks.

I. GEOLOGICAL RESULTS OF DEEP DRILLING ON THE ALFÖLD (BIG HUNGARIAN PLAIN)

Previous to the World War, H. de Böckh called attention to the oil and gas possibilities of the Alföld and of Transdanubia. He began and led systematic geological investigations during the war in a very thorough manner with modern methods. Böckh based his investigations chiefly on the maxima and minima of gravity recorded by the torsion balance of Baron Eötvös. He proposed the first deep wells of the Alföld on the basis of gravity surveys, whereas F. de Pávai Vajna, experienced in petroleum explorations on the Alföld and in Transdanubia, located his wells on subsurface structure drawn from surface dips in Pleistocene and Holocene strata.

The Hungarian State has drilled 9 deep holes on the Alföld, the records of which can be found in the report of de Böckh for 1930 and other publications. The systematic study of the material from the holes has been begun by the Royal Hungarian Geological Survey under the direction of de Böckh. Because of the great reduction of the staff of the Survey, the material from only 4 deep wells has been completely examined: Nagyhortobágy I, Hajduszoboszló I, Karcag I, and Vérvölgy I. The material of the holes Karcag II, Debrecen I, Hajduszoboszló II, and Tiszaörs I still requires much petrographical study and correlation.

[1] Read by title before the 16th International Geological Congress, at Washington, D. C., July, 1933. Manuscript received, December 20, 1933.

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At present only the Hajduszoboszló II well (2,037 meters in depth) is known to have entered the basement rocks of the Alföld. Below 1,619 meters in this hole were found gray semicrystalline limestones, dolomite, and multicolored marls, the age of which has yet to be determined. In a recent note published in the *Földtani Szemle*, K. de Papp is inclined to consider them representatives of the Lower Cretaceous Flysch and to correlate them with the Flysch of the Transylvanian Ore Mountains. Considering the semicrystalline structure the writer believes it more probable that the strata found at Hajduszoboszló are analogous with the early Paleozoic limestones of the Bükk Mountains.

The age of the continental hard, red sandstone found in the Debrecen I well, between 1,465 and 1,566 meters, is also unknown. The petrographic resemblance induced the Survey to correlate the beds at these depths with the Permian, but since Z. Schreter found in the underlying gray sandstone poorly preserved *Foraminifera* resembling *Haplophragmium*, *Gaudryna*, and *Cornuspira*, indicating Oligocene and Miocene, the age of the series from 1,465 to 1,738 meters is not yet determined.

It is interesting to note that the well on the maximum of Tiszaörs remained in Pannonian strata to the depth of 1,880 meters, as indicated by the discovery of Pannonian *Limnocardium* in the deepest dense sandstones.

Most of these holes produce, at depths ranging from 930 to 1,200 meters, great quantities of valuable hot mineral waters containing salt, iodine, and bromine, accompanied by 2,500–3,800 cubic meters of gas daily. The temperatures are 65°–75°C. The expenses of the wells at Debrecen and Hajduszoboszló have already been paid, especially the well at Debrecen, by income from the baths in the Nagyerdö and from the gas. The writer believes that the hot waters of the Alföld may be used not only for the heating of towns, but for horticultural purposes in glass houses and for the cultivation of rice.

Let us see now the stratigraphic results of the deep drilling. Pliocene sediments of the Alföld are surprisingly thick. The upper limit of the fossiliferous Pannonian strata has been found at different depths: at Hajduszoboszló, 140 meters; at Debrecen, 599; Tiszaörs, 770; and Szolnok, 870 meters. The base of the Pannonian strata has been found in the Hajduszoboszló well at 1,423 meters and at Debrecen at 1,318 meters, but at Tiszaörs fossiliferous Pannonian marls have still been found at 1,880 meters. Many signs indicate that the Pannonian strata of the Alföld are lenticular. Unfortunately the logs of the wells drilled by the State have not yet shown more detailed

petrographic or paleontologic evidence on the Pannonian strata. No good key horizon or good key fossils could be found. The horizons determined by Halaváts, Vitális, and Lörenthey about the littoral development of these formations are unserviceable in the Alföld, at least in the details. As *Gastropoda* and the different species of *Congeria*, *Limnocardium*, and *Unio* have a great vertical range, they are not good key fossils. The writer expects much better results from the study of the microfauna, particularly the *Ostracoda*. It is also expected that studies in sedimentary petrology will yield more evidence about the Pannonian series.

The Sarmatian and Mediterranean strata have been found in only two deep wells of the State. The Debrecen I well, between 1,318 and 1,347 meters, found Sarmatian limestones with brackish-water fossils, and from 1,347 to 1,465 meters, Mediterranean tuffs of dacite and rhyolite. The Hajduszoboszló II well found the Sarmatian limestone at 1,423 meters, and below it the dacite tuffs. As the Hajduszoboszló II well entered the crystalline limestones immediately below the dacite tuffs, it may be concluded that in this part of the Alföld no Tertiary sediments older than the Sarmatian were deposited.

The foregoing data about the top and base of the Pannonian strata indicate that the thick Neogene sediments of the Alföld are not horizontal. However, we do not know much about the structure of the Neogene formation of this basin. The results of the investigations with the Eötvös torsion balance and the data of the deep wells proved, however, that the Pannonian strata are remarkably disturbed, suggesting small fold-faults or flexures. It is not certain that the anticlines mapped by F. de Pávai Vajna on the surface are present at depth, in the Pannonian. Judged by the present data, the centers of the maxima found by measurements of gravity seem to be removed a little from the centers of the surface anticlines. This indicates that we must postulate deep in the Alföld asymmetrical fold-faults similar to those mapped by the oil companies in the great Neogene basins.

It is regrettable that we are not yet able to interpret geologically the results of the gravity measurements. The last deep well was located at Tiszaörs on the center of a geophysical maximum, but at 1,840 meters it was still in Pannonian strata with *Limnocardia*. The writer believes that the petrographic nature of the geophysical maxima and minima could be determined by seismic methods, which he proposed in 1930.

A very important result of the deep drilling by the State is the discovery that the showings of gas and bitumen do not disappear with increasing depth. The Hajduszoboszló II hole found gas and oil

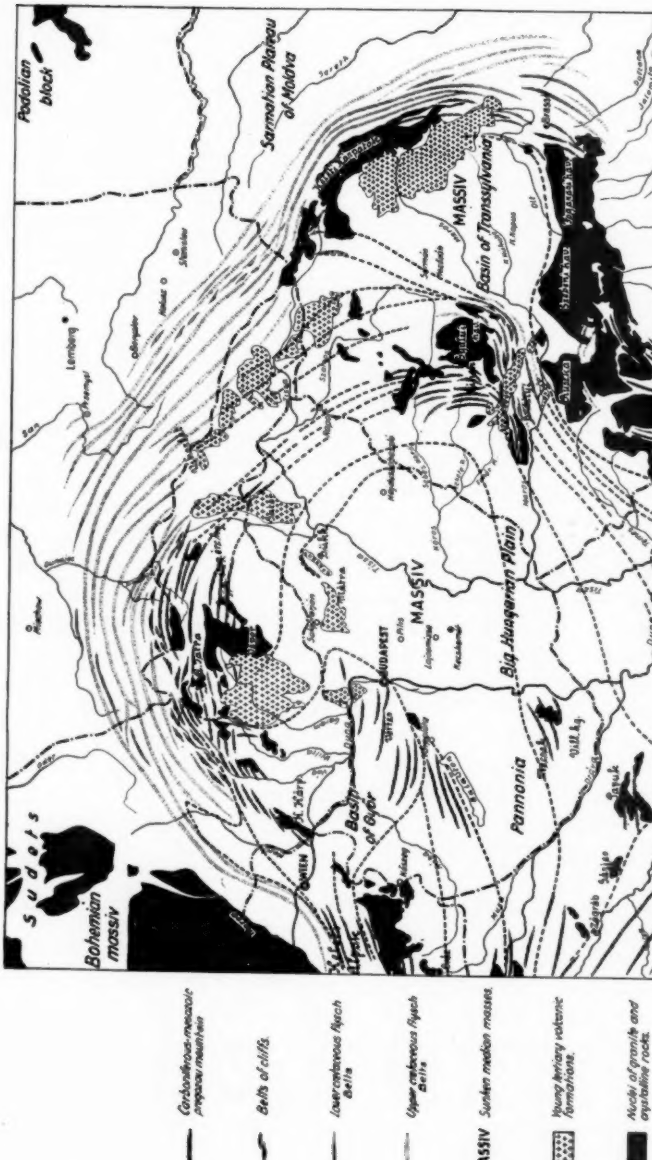

FIG. 1.—Sketch map showing Hungarian mountain system. West-east distance of area shown, approximately 700 miles.

showings between 1,617 and 1,629 meters and at 1,985 meters. This indicates that the gas of the Alföld is not recent marsh gas originating in the Pannonian and Levantinian strata, but it is gas migrating from considerably older formations.

II. TECTONICS AND PALEOGEOGRAPHY OF BASIN SYSTEMS OF HUNGARY

Hungary, having been dismembered by the peace treaty of Trianon, is confined now to a great part of the Alföld (Big Hungarian Plain) and Pannonia (Transdanubian district). These two geographical units, which are separated from each other by Danube River, represent a median mass of undisturbed structure between the orogen ranges of the Carpathians and the Dinarides. The Alföld is to-day one continuous basin, whereas Pannonia is divisible into several basins and the block mountains separating them. The orogenic belt of the Carpathians is bordered on the outside by the continuous girdle of the Carpathian Flysch sandstones, whereas on the inside it is bordered by diverse rocks of very different ages and facies. On the borders of the basins and in the block mountains, besides granites and crystalline schists, there are also Devonian, Carboniferous, Triassic, Jurassic, Cretaceous, Eocene, and Oligocene sediments.

The original basement of the great system of basins is formed by Variscian ranges composed of Permian sedimentary rocks. The area of the Alföld and of Pannonia was occupied in Paleozoic and Mesozoic time by alternating massifs and shallow sea basins in a zonal arrangement; it was an archipelago.

The Variscian massifs were formed by island-like nuclei of granite and crystalline schists similar to the nuclei of the Western Carpathians and the mountains of Slovenia and western Servia. The Permian-Cretaceous sediments of the shallow sea basins were folded in Mesozoic time zonally into open folds forming ranges of mountains. Thus Kimérian and Pregosau folds formed the island-like mountains of Hungary: the range of Bakony-Budapest-Bükk and the mountains of Pécs and Villány. After the Upper Cretaceous, slow and uniform upheaval of the Alföld began, as the result of epeirogenetic movements. The pre-Tertiary structures produced by folding and overthrust have been followed by a period of faults which is still going on. At the beginning of the Tertiary the whole area of the Alföld was dry land, which began to sink in the Oligocene and Miocene in consequence of epeirogenetic movements. The paroxysm of this sinking took place between the Lower and Upper Mediterranean,

FIG. 1.—Sketch map showing Hungarian mountain system. West-east distance of area shown, approximately 700 miles.

nearly simultaneously with the eruptions of andesites of the Hungarian Highland.

In the genesis of the Hungarian system of basins thus repeatedly alternating, upheaval and sinking played an important rôle. The upheavals were connected with regressions and the rise of orogens, whereas the sinkings caused transgressions of the sea. There was an orogen in the Upper Permian, in the Lower Cretaceous (later Kimérian Mountains), then in the Upper Cretaceous (the so-called Pregosau or Austrian Mountains). The Tertiary also brought movements: between the Eocene and the Oligocene, the Pyrenean; and between the Oligocene and Miocene, the so-called Savean movements; but these showed epeirogenetic character and produced fault mountains.

The Mesozoic transgressed together with the Permian upon the Variscian basement, as proved in the Bakony, Bükk, and Mecsek mountains. The second great period of transgression followed in the Lias, when the productive coal deposits of Pécs and Steierlak were formed. A transgression of rather great extension occurred in the Upper Cretaceous (Cretaceous coal of Ajka). The Tertiary also brought repeated transgressions of the sea, as at the beginning and at the end of the Middle Eocene, and in the Lower and Upper Miocene. It has been stated that the transgressions of the Tertiary seas came without exception from the Vienna Basin. At the beginning of the transgressive periods in the bays of the Variscian and Kimérian mountains, the Eocene coal measures of Tata-Esztergom and of the Bakony, the Oligocene coal measures of Esztergom and of the Bakony, and then the Miocene coal measures of Salgótarján and of the basin of Borsod were deposited. The Eocene bauxites of the Bakony and Vertes mountains originate from the *terrarossa* of the continental period between the Cretaceous and the Eocene.

The exposures in the bordering and island mountains indicate that in the Kisalföld (Small Hungarian Plain) and along the northern border of the Alföld a broad geosyncline of Paleogene and Miocene age formed a communication between the Vienna Basin and the Transylvanian Basin. It is characteristic that the salty Miocene formations exposed in the northwest corner of the Alföld show the Transylvanian facies. But neither the older Miocene nor the Paleogene sea filled the Hungarian basins entirely. Most probably these seas found more extensive basins only in the north in the area of the Kisalföld, along the Matra and Bükk mountains, and in the south, along Drava River. The whole Hungarian system of basins was probably not completely submerged before the Upper Mediterranean. The greatest part of the area is occupied to-day by Pontic or Pannonian Pliocene

sediments, which cover the older rocks to depths of 600–2,000 meters. In the Upper Pliocene the whole area was dry again. After the Levantinian the rivers overflowing the Alföld filled the area with their detritus and formed lakes with fresh water. The process of sinking, however, was not yet finished. The basin of Lake Balaton, for instance, sank in the Pleistocene.

The Royal Hungarian Office of Triangulation demonstrated by exact levels that during the last 40 years the mountains of the Balaton Highland, Budapest, Bükk, and Pécs did not change in elevation, whereas the Bakony and the territories north of it rose and great parts of the Alföld sank. The highest amount of the upheaval during the last 40 years was 202 millimeters in Bakony Mountain; the maximum of sinking 150 millimeters between Szentes and Karcag. These data show that the continuous epeirogenetic sinking of the Alföld and the slow upheaval of Bakony Mountain and the basin of Györ is still going on.

For proper study of the tectonics and paleogeography of the Neogene basins of Hungary, the stratigraphy of the Tertiary rocks of the island mountains must be considered.

Natural indications of oil are to be found at several places of the border and median mountains.

Oil showings are known in the northern parts of the Alföld, in the Mátra Mountains near Recsk, Parád, and Nagybátony, generally in connection with the Paleogene strata.

In the Villány Mountains the sulphuric thermal water of the Harkány Bath brings up oily films. Opposite the southern part of the Comitate Zala, only a few kilometers from the boundary, there is a little oil territory on Mur Island, where in the last 10 years about 600 tanks of heavy oil have been produced from Pliocene strata.

Very important are the Sarmatian sands and tuffs containing 10–16 per cent asphalt, found in the north, between Bogács, Tard, and Sály in boreholes drilled along a line of about 12 kilometers, and the extensive asphalt deposits on the eastern margin of the Alföld near Bodonos, Derna, and Tataros. Systematic exploitation of the last mentioned has gone on for several decades. Probably both occurrences of asphalt are the results of fossil oil migrations which came from Paleogene or older mother rock.

To the oil showings might be added the Upper Oligocene brown coal of Szapár and Jásd in the Bakony Mountains, with 48–54 per cent bitumen.

The Triassic Recoaro and plate limestone of the Balaton Highland and the Lower Cretaceous black Requienia limestones of the Bakony and Villány mountains are very bituminous.

TABLE I

GEOLOGIC COLUMN OF THE TERTIARY IN THE ISLAND MOUNTAINS OF HUNGARY

Pleistocene		Loess, river gravel
Pliocene	Levantinian	Gravel with *Paludina*, clay, sand
	Pontian (Pannonian)	Clay with *Congeria*, sand, sandstone
Miocene	Meotian	Conglomerate, clay, fresh water, limestone
	Sarmatian	Coarse limestone with *Cerithium*, clay, gravel, coal measures. Shales with *Diatomea*
	Tortonian	*Leitha* limestone, clay, sandstone, coal measures. Eruption of andesites
	Helvetian	Limestone with *Bryozoa*, sand, clay, coal measures
	Burdigalien	Layers of sandy clay with *Pecten praescabriusculus* (Schlier)
Oligocene	Aquitanian	Coal measures of Salgótarján
	Cattian	Sand and sandy clay with *Pectunculus obovatus*, sandy clay with *Foraminifera*, layers with *Cyrena*
	Rupelian	Mudstone of Kiscell
	Ligurian	Marl of Buda. Shales with fishes near Buda and Eger (Menilitshales)
Eocene	Priabonian	Marls with *Bryozoa*
	Bartonian	Limestone with *Nummulina* and *Orthophragmina*
	Auversian	Limestone with *Nummulina* and *Orthophragmina*, marly limestone with *Miliolidea*, bituminous limestone. Brackish-water sand, clay and limestone. Layers with coal
	Lutetian	Marl with *Perforata*
	Ypresian	Clay and marl with *Operculina*, fresh-water limestone with coal measures. Coal districts of Esztergom, Tata, Bakony
Paleocene		Continental period
		Deposits of bauxite
	Danian	Continental period
	Senonian	Limestones with *Hippurites*
Cretaceous	Turonian	Gosau strata, coal measures at Ajka
	Gault	Sandstones, marls
	Neocomian	Bituminous limestone in Bakony and Villány mountains

III. TECTONIC CONNECTION BETWEEN MOUNTAINS OF EASTERN FRONTIER AND NORTHERN CARPATHIANS

In exploration for petroleum and salt the tectonics of the Carpathians and of the mountains of the eastern frontier also must be taken into consideration. The contrast between the now generally accepted synthesis of the Carpathians, based on the theory of nappes, and the explanation of the Hungarian basins by tectonics, characterized by faults, has lost much of its sharpness. After the competent work of Rudolf Staub entitled, "Der Mechanismus der Erde," advocates of the nappe theory concede also the correctness of the interpretation that the somewhat undisturbed median masses surrounded by orogen ranges are more or less autochtonous and must not in every case be considered as having been transported there from great distances by *charriage*. On the other hand, advocates of the con-

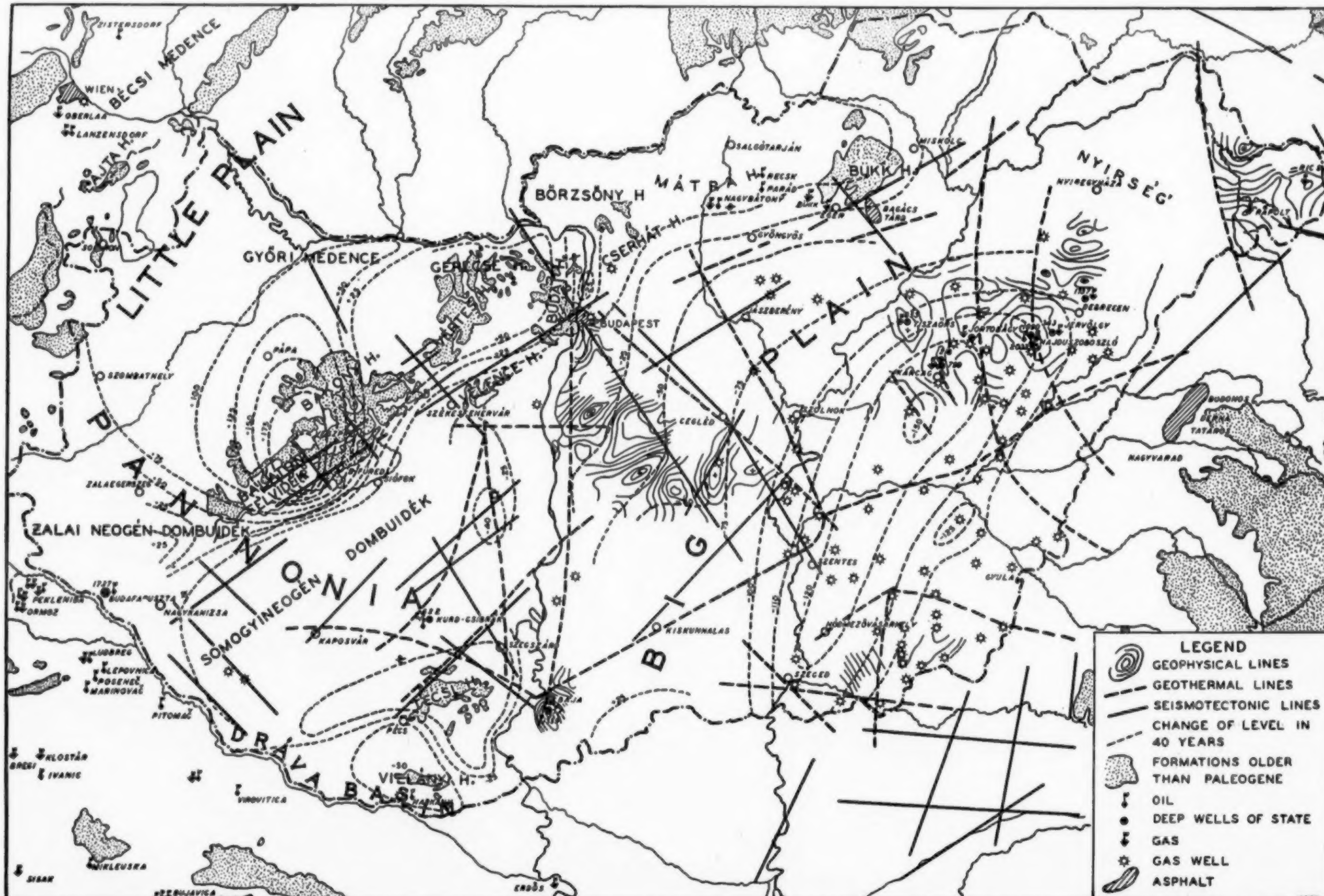

FIG. 2.—Geophysical and tectonic sketch map of Hungary compiled in 1932 by the Hungarian Geological Institute. West-east distance, approximately 350 miles

cept of fault tectonics recognize the Pregosau and Kimérian imbricate structure and in accordance with this the zonal character of the facies ranges of the Transdanubian middle mountains and this also has helped to harmonize the two different conceptions. To-day it is possible to state that the Triassic mountain range of the Balaton Highland is the more or less autochtonous continuation of the central nappe zones of the Alps, which shows here a simpler structure of Kimérian and Pregosau folds. Following the investigations of prominent specialists of the Trias, the writer believes that the Trias of the Nagyszál, of the mountains of Buda, the Gerecse and Vértes mountains, and perhaps even of the Upper Bakony differs in its facies from that of the Balaton Highland, since it corresponds especially with the Karnian rather than with the Choch facies of the Chalk Alps and of the Northwestern Carpathians. This means, that while the Trias of the Balaton Highland represents in paleogeographic respect the continuation of the Trias zones of the central Eastern Alps, the development of the Trias from Bakony and Budapest is related to that of the Northern Chalk Alps and of the Western Carpathians, so that it might be supposed that the latter had been deposited in another, separated geosyncline.

But the final explanation of the connection between the structures of the Hungarian Neogene basins and the older border and island mountains surrounding them, can not yet be given. Especially the regional tectonics of the eastern border of the Alföld and their connection with the Carpathians are not yet sufficiently explained. Since in the Alföld the question of gas, petroleum, and salt is closely connected with the tectonics of the Carpathians and Ore Mountains, the writer must also sketch his opinion concerning the latter.

Similar to the Alföld, the basin of Transylvania represents also a less complicated median mass. In the depth of both masses Variscian and Vindelician mountains are buried, with the difference, however, that the sinking of the basin of Transylvania took place before the Upper Cretaceous, and that of the Alföld only in the Middle Miocene.

A glimpse at the geological map of the Northern Carpathians shows that the ranges of the inner Carpathian facies can be followed only as far as the valley of the Hernád. Though the sandstone zone of the Beskids and the Pienine belts follow the strike of the outer Carpathians east-southeast, the nuclei of the granitic mountains together with the zones of the high tatric and subtatric nappes, which are called by Matejka and Andrusov "tatrides, granides, gemerides,"[3] pinch out suddenly at the valley of the Hernád, where the great

[3] Name derived from Gömör Mountains.

andesitic mountain extending from Tokaj to Eperjes occupies their place. In the east the remains of the gemerids show themselves once more in the fault blocks of the Comitate Zemplén.

In the northeast part of the Alföld the inner Carpathian orogen ranges sank in Tertiary time. Many signs support the writer's opinion that the aforementioned Pregosau inner Carpathian orogen belts, with a part of the Beskid-Flysch belt, diverge in a sharp curve south-southeast from the range of the Northeastern Carpathians, which are built up of the pre-Paleogene Pienine and Beskid belts. Southward of the Carboniferous fault blocks of Zemplén, in the Réz and Királyerdö mountains, as well as in the Kordru and the Bihar mountains, the writer recognizes the next exposures of the inner Carpathian orogen belts, namely, the tatrids, granids, and gemerids. Thus, in his opinion, the outer and inner Carpathian orogen belts diverge, giving place to an autochtonous median mass, which is the basement of the basin of Transylvania. This tectonic idea corresponds well with a fact already recognized by the writer's father, L. de Lóczy: that the Paleogene sandstone belt surrounds the Bihar and Hegyesdrócsa mountains from Zsibó as far as Lippa in a similar regional position to that of the Flysch ranges of the Northwestern and Northern Carpathians.

The Carpathian sandstone belt, which can be followed from Zsibó through Hesdát and Szászlóna as far as Torda, consists of less complicated autochtonous Paleogene formations, whereas from Torda to Lippa the Lower and Upper Cretaceous Flysch and the inner cliff belt joins them in folded nappes. Between Torda and Lippa the rootless white cliffs of the Flysch belt, consisting of Malm limestones, show a striking resemblance to the Pienine cliff ranges of the Northwestern Carpathians.

The Upper Cretaceous formations are however found also in the Réz and Királyerdö mountains; in the latter even the Lower Cretaceous is represented. This recalls conditions in the Northwestern Carpathians, where in the valleys of the Poprád and Vág the Flysch occurs between the inner Carpathian ranges.

It is known that the Upper Cretaceous sediments transgress with the Cenomanian upon the folded Flysch, indicating that the orogenesis of the Ore Mountains also took place in Pregosau time.

If we consider the semicircular Flysch wreath surrounding the Hegyesdrócsa Mountain from the direction of Transylvania, we conclude that the inner Carpathian nappe belts starting from the valley of the Hernád southward, turn in the Hegyesdrócsa Mountain north of the valley of the Maros in a right angle westward and dis-

appear under the Alföld. Farther west, in the mountains of Pécs, in the Fruskagora, and in the Papuk Mountain of Slavonia, they appear again on the surface. The Upper Cretaceous and Paleogene formations of the Fruskagora and the Majevica planina, the writer believes to be the western representatives of the Flysch wreath.

From the Bihar Mountain southward to the Danube on the eastern border of the Alföld, as neither the Paleogene nor the Upper Cretaceous formations are known, it may be concluded that the older mountain ranges sank along a system of sharp faults.

The Paleozoic-Mesozoic ranges of the Comitate Krassószörény are tectonically not the continuation of the zones of the Transylvanian Ore Mountains. South of the Maros they turn in a right angle eastward and can be traced farther in the mountains of Brassó and in the Nagyhagymás.

IV. RESULTS OF TECTONIC AND PALEOGEOGRAPHIC SYNTHESIS

The more recent views on the Neogene basins of Hungary, set forth in the preceding paragraphs, involve also new ideas about exploration for salt, oil, and gas. This comparison with the data furnished by the State's deep wells beyond the Tisza leads to the following conclusions.

1. The thickness of the Pannonian on the Alföld is very considerable and ranges from 1,400 to 2,000 meters, according to the depth to which the Paleo-Mesozoic basement rock had sunk.

2. Folded buried hills are probably not present in the depth of the Alföld. It is probable, however, that the pre-Paleogene basement is divided along fracture planes of different ages into horsts and through faults.

3. Though the old basement rocks have probably a faulted structure, the thick plastic Neogene filling the basin shows a structure of folds and flexures, which, however, lack the regional development characterizing the folded mountain ranges. To judge by analogy with the characteristic structures found by oil development in the great Neogene basins, it seems probable that the folds of the Pannonian strata of the Alföld have also a genetic relation to the system of faults of the basement as well as those of the bordering and island mountains.

The seismic and geothermic investigations, as well as the precise levelling done by the State, lead to the conclusion that the blocks of pre-Neogene rocks forming the basement of the basins possess faulted structure similar to that of the island mountains. This struc-

ture may resemble that of the Vienna Basin, which is now better known since the drilling near Vienna and at Egbell.

Not only brachy-anticlines and brachy-synclines, but asymmetric folds and flexures connected with the faults at depth are factors in the Alföld too. H. de Böckh has already concluded from the results of the geophysical investigations that the Pannonian folds are asymmetric.

The Pannonian formations of the parts of the Alföld beyond the Tisza show lenticular structure, and their detailed synthesis is rendered very difficult by the absence of diagnostic horizons and fossils.

4. In the territories tested by deep drilling the Sarmatian and Mediterranean formations seem to be partly developed, namely, in the Transylvanian facies characterized by dacite tuffs.

5. The presence of the Paleogene at depth is more or less improbable, so that the sinking of these parts of the Alföld must be placed at the present in post-Paleogene time.

6. The age of the sunken rocks forming the basement of this part of the Alföld has yet to be determined. A most important feature, however, is the metamorphosed character of the limestone found in the deep well Hajduszoboszló II.

7. To judge from the results of deep drilling, the gas is not recent marsh gas of Levantinian and Pannonian age, but originates from older formations. Though reservoir rocks, suitable for accumulation, and impervious overlying strata are not missing, the quantity of the hydrocarbons found in the deep holes has been relatively small, indicating (as deduced also from experiences in other countries) that the migration of the hydrocarbons took place not vertically from below, but laterally, from the sides. This is a phenomenon very often met with in the great Neogene basins developed in a lenticular facies. The writer has observed similar conditions in southern Palembang and Djambi on Sumatra. The oil and especially the gas may migrate very considerable distances horizontally, provided that basin sediments of great extent and impervious covers are present. This explains the fact that hydrocarbons may accumulate in dome-like structures situated at very great distances from the mother rocks.

8. Though the mother rocks of the hydrocarbons of the Alföld are still in many respects problematic, the foregoing facts yield some basis for further exploration. Thus drilling must be continued at places where at depth the presence of older Tertiary or Cretaceous rocks can be expected. Such places are to be sought along the northern border of the Alföld, where not only the Neogene, but the whole Paleogene series is developed.

As is shown by the data of the bordering and median mountains of the Little Plain and along the northern margin of the Alföld, there existed a broad geosyncline of Paleogene-Miocene age, which established a communication between the basins of Vienna and Transylvania.

In the southern part of Pannonia, along the plain of the Dráva another Paleogene geosyncline extended from west to east between the Bay of Graz and the mountains of the Fruska Gora. Judged from the neighboring oil and gas occurrences of Jugoslavia and from the gas indications of Nagyatád and Lábod, this might be a promising territory.

Exploration for hydrocarbons ought to be continued also on the northern border of the Alföld. This suggestion is in a great degree supported by the fact that in the northern part of the country many indications of oil, asphalt, and gas are known. Important oil showings have been found near Parád, Recsk, and Nagybátony, which originate most probably not from the Miocene schlier, but from the Oligocene. The writer is informed by J. Noszky that inflammable gas erupted from a depth of 400 meters from the well drilled not long ago near Diósjenö, which entered also the Upper Oligocene. Remarkable also are the bituminous coals of Ormospuszta studied by J. Vitális, which can be considered also as indications of oil.

The greatest importance, however, should be attributed to the asphaltic formations near Bogács and Tard, exposed first by K. Minich in 1908 in the Szekrény valley and recognized first by Baron F. Nopcsa in a note published in 1929, as an important indication of oil. Though the asphalt has been found at the base of the Pannonian, the mother rock of the oil, the condensation of which furnished the asphalt, is probably Paleogene in age, a supposition suggested also by the presence of the complete Tertiary series in the bordering mountains rising above Bogács.

Besides, near Budapest a whole series of deep wells yielded gas; for example, the 230-meter well at Veresegyháza produced 30 cubic meters of methane before it filled with mud. In the wells at Örszentmiklós (400 meters), Rákospalota, Pestszenterzsébet, and even in the old artesian well drilled by Zsigmondy in the Városliget (a park in the eastern part of Budapest) more or less gas was found in Oligocene strata. Gas accompanied by salt water containing iodine appeared in the artesian well at the Eger distillery, and in the 400-meter test well at Diósjenö. The gas in both wells came from the Oligocene.

Source rocks in the northern parts of the Alföld may be represented by the Middle Oligocene fish-shales in the mountains of Buda

and near Eger; also, certain marls of the Eocene and Oligocene and the mudstone of Kiscell, all containing *Foraminifera*. We may consider also the bituminous limestones of the Cretaceous Flysch, provided they are present on the sunken basement rocks of the Alföld.

Rocks suitable for the accumulation of oil and gas occur also on the Alföld. Especially the thick lenticular strata of the Pannonian sand, the porous Miocene limestones, and the Upper Oligocene sands containing *Pectunculus obovatus* are suitable for the accumulation of gas. These formations are generally extensive and deeply overlain by the Pannonian, Levantinian, or Mediterranean schlier-clays.

Since it can be assumed, in the geologic section from Karcag to the bordering mountains of the lower part of the Comitate Máramaros that is, to Ricse, that rocks of many different kinds and ages are hidden below the Neogene strata of the Alföld, there must also be source rocks among them. This is proved by the gas-producing holes drilled by the State. If the Flysch belt surrounding the inner Carpathian ranges really continues at depth through the northern and eastern parts of the Alföld, it may be assumed that the mother rocks of the gas and oil indications of the territories beyond the Tisza are to be sought in it. In fact, both the Hajduszoboszló and Debrecen wells prove that the Sarmatian and Mediterranean formations are developed here in the Transylvanian facies. This is supported also by the geological structure of the bordering mountain rising near Turricse in the part of the Comitate Máramaros occupied by the Roumanians. The presence there of salt bodies which have been considered Mediterranean in age and the presence of the Paleogene Flysch with oil showings suggest that along Tur River, in the Hungarian part of the Comitate Szatmár, these formations will be encountered at depth. But we must consider also the narrower Flysch belts between the inner Carpathian zones as factors in the Királyerdö and Réz mountains as well as in the Northwestern Carpathians.

The surface morphology of the Alföld does not lead to many conclusions concerning the tectonics with depth. However, the peculiar break in the course of the Tisza near Csap suggests certain conclusions. It seems very probable that the section of the Tisza between the mouth of the Szamos and Csap follows a sharp tectonic line separating different tectonic regions of the Nyirség and the territory east of it.

The mother rocks of the oil occurrences of Zsibó and Batiza as well as the asphalts of Derna and Bodonos are not yet determined. Probably they are Eocene, but it is not impossible that they are Lower Cretaceous (baremian) Flysch. It is only certain that these important

occurrences of hydrocarbons are related to the Carpathian Flysch belt or to the autochtonous Paleogene of the basin.

The writer believes that the solution of the most important stratigraphic and tectonic problems in exploration for oil and gas is to be sought in the territory between the Transylvanian Basin and the northeastern section of the Alföld, namely, in the Meszes Mountain, in the Szilágyság as well as in the environments of the Szamos and Lápos rivers, where during the Tertiary the sea might have communicated repeatedly along the Bükk and Mátra mountains with the Vienna Basin.

As the salt formations are genetically closely related to the hydrocarbons and commonly occur with them, the salt possibilities of Hungary may be discussed with the geology of oil and gas.

To-day we must give up that obsolete, optimistic idea that the Mediterranean salt clay, the so-called "schlier," should be generally present at depth in the Alföld. Though most of the deep wells beyond the Tisza yielded mineral waters with large quantities of salt, iodine, and bromine, it is rather improbable that productive Miocene salt bodies will be found there. Conditions seem more favorable east of the Nyirség, where we may expect at depth the sunken continuation of the productive salt formation of the Comitate Máramaros. The age of the deposition of the salt is not definite, either in the Transylvanian Basin, or in the Comitate Máramaros. H. de Böckh derived the salt formations of the Transylvanian Basin from the Mediterranean schlier and was inclined to trace the salt possibilities of Hungary also on this basis. Many signs indicate that the salt formations of the Mezöség (Transylvanian Basin) were deposited not only in the Mediterranean, but repeatedly during the Lower Tertiary. Because of oscillations of the earth's crust a great part of the Transylvanian Basin dried up at least four times after having been overflowed by the deep sea.

Thus, not only in the Middle Miocene, but much earlier, in the Middle Oligocene, or probably even in the Upper Eocene, salt and hydrocarbons could have originated here. It is certain that in the Transylvanian Basin the Schlier formation could nowhere be found in a normal stratigraphic contact with overlying and underlying beds, either in the deep wells, or along the salt bodies. On the basis of his own explorations the writer believes that the enormous quantities of gas of the Mezöség, together with a great part of the salt, came into existence chiefly in the Lower Tertiary, primarily in the Middle Oligocene. This opinion is supported by the fact that the fish-shales of Nagyilonda (equivalents of the Menilite shales) are found in the

southern and western parts of the basin, near Fogaras and Gyulafehérvár, showing that they are present at depth in the whole basin. Very important also is the statement of K. Hofmann, that the fish-shales occur also between the Bükk and Lápos mountains. The dry gas, after having passed an unknown filtering process, might have forced its way up, together with great parts of the salt, from very considerable depths through tectonic fissures. The Transylvanian salt excemas are, according to this conception, secondary deposits brought up by Pliocene movements.

On no account can we accept the exaggerated opinion of Popescu Voitesti, who suggests that the salt formations of the Transylvanian Basin came from still greater depths, namely, from Jurassic and Cretaceous rocks, all the less, as the sinking of the basin took place only at the beginning of the Upper Cretaceous.

If we consider now the salt possibilities of Hungary and study the salt indications now known in the light of the foregoing facts, we must conclude that we have in Hungary at least two formations of salt clays. One of them is the Mediterranean schlier, which, according to data now available, will hardly yield exploitable quantities of salt, except the territory of the Comitate Szatmár in Hungary. The second one is the Middle Oligocene schlier, the so-called "mudstone of Kiscell," which may be the mother rock not only of the salt, but also of the oil and gas.

The water of the Pestszenterzsébet well containing 12 gr. of salt in 1 liter, the salt water of Eger containing iodine, the salt indications near Parád, Sóshartyán, Kishartyán, Pásztó, et cetera, are all connected with the Oligocene mudstones and not with the Mediterranean schlier.

If we succeed in finding areas where the salty mudstone is capped by thick clayey Miocene or Pliocene strata and where the structure is also suitable, we may have new hopes of finding, besides hydrocarbons, also exploitable quantities of salt.

Finally, we can state that in the Alföld it is not the Mediterranean schlier, but the salty clay of the Paleogene range of Budapest-Mátra-Bükk, namely, the mudstone of Kiscell, that may be considered the mother rock of the salt.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 942-947

GEOLOGICAL NOTES

TWO DECADES OF PROGRESS IN THE ART OF OIL FINDING

Cushing, Oklahoma, was discovered in March, 1912. In December, 1913, oil was found in the Bartlesville sand, and extremely rapid development ensued. The writer has very distinct recollections of the debacle which followed with the large quantity of oil thrown on the market at that time. It caused almost as much demoralization in the oil industry as has the East Texas field.

The outbreak of the World War in 1914 of course rapidly reversed this situation. As the war spread, the demand for petroleum rapidly increased, so that the over-production from Cushing did not afflict the industry for so long a period as has that of East Texas.

The structural conception of oil accumulation now universally recognized was then but faintly visualized, and among the practical men of that time engaged in the oil-production business—with possibly a few exceptions—was entirely ignored. The anticlinal theory of oil accumulation was of course well known to the geologists in the days before Cushing, but practical men paid little or no attention to it.

Faults were viewed with disfavor as places to look for oil, and fault structures of the Mexia-Powell type were not visualized. The Texas geologist of that day knew nothing of the Bend arch, the Amarillo axis, the Wichita axis, the Mexia-Luling fault system, the Marathon fold, the West Texas "Big lime," the East Texas "shore line," Conroe trend—or their implications from the standpoint of oil accumulation. The art of oil finding was still in its infancy and the kaleidoscopic changes and improvements that followed in the two succeeding decades were not suspected.

In the Gulf Coast, following the Lucas discovery at Spindletop, exploration consisted of search for topographic mounds similar to that at Spindletop. Search for active gas seepages and associated "paraffine dirt" deposits, led to the discoveries at Sour Lake, Batson, Saratoga, Humble, Goose Creek, and proved salt-dome structures at Barbers Hill, High Island, West Columbia, Damond Mound, and elsewhere.

Prominent surface indications of the type indicated had become

increasingly difficult to find by 1920, the country having been fairly well combed. In that year attention was focused to the significance of sulphur-water wells, leading to the discovery of Big Creek oil field and Boling sulphur field.

About 1921 there was established in Houston, by the Rio Bravo Oil Company, for the first time, a laboratory for the microscopic examination of cores obtained from wells, initiating the method of correlation by means of microscopic fossils. Coring of formations by means of coring devices, enabling the geologist and the laboratory worker to get actual samples of the formations underground likewise got under way about the same time, aiding materially in the exploratory development.

The Rycade Oil Company and the Shell Company introduced the torsion balance into the Gulf Coast about 1922, initiating the period of torsion-balance exploration.

At the Dallas meeting of the Association in 1920 Dr. Udden read a paper entitled "Suggestions of a New Method to Make Underground Observations," proposing the use of the seismograph in connection with artificial explosions of dynamite to measure the depths to the Ellenberger limestone, outlining at that time the principle now used in reflection shooting. The writer vividly recalls the impression made upon him by this suggestion, which to many then seemed to be fantastic and impracticable. The Marland Oil Company began the use of the seismograph on the Gulf Coast in 1924, four years after the publication of the Udden paper, employing the refraction method for the purpose of locating salt domes. Following the period of refraction shooting, the art of reflection shooting employing the method suggested by Udden was successfully introduced into the Gulf Coast. At the present time geophysical exploration continues unabated in the Gulf Coast, and this method of exploration has spread to practically all possible oil- and gas-bearing areas in the United States.

In the hard-rock country, profound changes and improvements in exploratory development have likewise followed since the days of Cushing. Previously, structure was delineated on maps by means of strike-and-dip arrows. Geologic observation consisted of strike-and-dip measurements of isolated outcrops. With the structural theory of oil accumulation definitely proved in Oklahoma and elsewhere, the methods of geologic mapping were vastly improved. The method of delineating structure by means of contours came into vogue, and with it the use of the plane table to measure elevations on key beds at different outcrops. Plane-table mapping in the hard-rock country reached its heyday about 1920 and 1921 following the Ranger

discovery, when much of Oklahoma, Kansas, and West Texas was mapped in this manner. (The Ranger development in 1919 had proved the existence of the Bend arch.)

Following this period the core drill was introduced. Marker beds were drilled to, and structure mapped on the basis of, these marker beds. Much of the faulted area in the counties north and east of Powell was mapped in this manner, after the discovery of the fields in the Mexia-Powell district. As has been noted, geophysical methods were introduced into the hard-rock country after their demonstrated success in the Gulf Coast.

The record of two decades in the development of exploration is a brilliant one, not surpassed by developments in any other line of human endeavor. The geologist can well be proud of these achievements.

ALEXANDER DEUSSEN

HOUSTON, TEXAS
February 28, 1934

TYPE SECTION OF HERMOSA FORMATION, COLORADO

Anyone working on the stratigraphy and lithology of the Pennsylvanian formations in Colorado is at once confronted with the almost insuperable obstacle of lateral transition of the facies. This is a difficulty even in areas of continuous outcrop. Confusion has been added by miscorrelation of beds whose fossils are not of the same age. In order fully to understand the problem it is perhaps first necessary to determine where the positive areas were and thus to locate the source of the sediments. To make the correlations necessary for this synthesis an intimate knowledge of the contained fossils is indispensable, but even the use of fossils is complicated by the fact that the faunas tend to change with the lithologic facies. With this problem in mind, and as the Hermosa is a very important unit of the Pennsylvanian system in southwestern Colorado, the writer believes that a detailed type section of it with some of the diagnostic fossils indicated will be of help to anyone working in the area.

A. C. Spencer,[1] who first named the Hermosa formation, described an area which covered many square miles, but gave no specific place as a type locality. His description follows.

> Occurring between the Devonian limestone and the typical red beds, and sharply defined from each, there is a heterogeneous series of rocks which is generally distributed in the San Juan region, where it reaches a maximum thickness of about 2,000 feet. It is characterized throughout by a brachiopod fauna of Coal Measure age, thus corresponding with the Missourian stage

[1] *U. S. Geol. Survey 21st Ann. Rept.* (1899–1900), Pt. II, p. 48.

of the Pennsylvanian series as it occurs in the Mississippi Valley. Some of the more common characteristic fossils are *Fusulina cylindrica, Productus semireticulatus, Productus nebraskensis, Productus cora, Spirifer cameratus, Chonetes mesolobus.* This group of strata will be called the Hermosa formation, from the large creek of that name entering the Animas River in the Durango quadrangle.

Since Spencer gave no specific type locality of the Hermosa, the stratigraphic section here shown as Table I was chosen for these reasons: (1) the section is easy of access, as the main highway between Durango and Silverton passes through the area; (2) the total thickness of beds is approximately the same as the maximum given by Spencer for the Hermosa; and (3) the section is located in the area considered typical of the Hermosa by Spencer and is well within the area mapped as Hermosa by the Geological Survey of Colorado.

The composite section (Table I) was measured by the writer in October, 1933. Several detailed sections of the hill located in Secs. 26 and 35, T. 37 N., R. 9 W., La Plata County, Colorado, were made and are here presented as a composite section with some of the diagnostic fossil horizons indicated.

TABLE I

COMPOSITE TYPE SECTION OF HERMOSA FORMATION

Sections 26 and 35, T. 37 N., R. 9 W., La Plata County, Colorado

RICO PERMIAN

Unconformity

HERMOSA PENNSYLVANIAN (DES MOINES-CHEROKEE)

Bed No.	*Interval Feet Inches*	*Total Thickness Feet Inches*	*Description*
60	100	100	Reddish maroon shale and some massive cross-bedded sandstone
59	10	110	Rubbly gray marl and gray-green limestone
58	72	182	Gray and maroon-to-variegated shale and some sandstone
57	140	322	Reddish maroon and gray shale with thin beds of sandstone and marl
56	10	332	Gray-green marl, limestone, and sandstone. *Prismopora* sp.
55	15	347	Thin-bedded sandstone
54	104	451	Variegated shale, marl, and sandstone. *Fusulina meeki* in lower part
53	16	467	Sandy gray-green limestone. *Fusulina meeki* and *F. hartvillensis*
52	36	503	Dark gray and maroon marly shale. *Fusulina hartvillensis* at base
51	40	543	Massive arkosic sandstone, very coarse, conglomeratic at base, containing pink pebbles of granite
50	6	549	Reddish dark gray sandy shale, variable thickness
49	31	580	Greenish soft sandstone
48	10	590	Rubbly dark gray limestone
47	31	621	Massive cross-bedded sandstone
46	26	647	Greenish micaceous thin-bedded sandstone
45	31	678	Black oölitic fossiliferous limestone with black shale shells. *Wedekindellina coloradoensis* and *excentrica*

TABLE I (Continued)

COMPOSITE TYPE SECTION OF HERMOSA FORMATION

Sections 26 and 35, T. 37 N., R. 9 W., La Plata County, Colorado

Bed No.	Interval Feet	Interval Inches	Total Thickness Feet	Total Thickness Inches	Description
44	46		724		Black shale
43	52		776		Sandstone shells and black shale
42	15	6	791	6	Gray limestone. *Fusulina rockymontana*, *F. hartvillensis*, and *F. minutissima*
41	124		915	6	Black micaceous shale
40	46		961	6	Dark gray-green sandstone and black shale, calcareous in places
39	67		1,038	6	Greenish thin-bedded sandstone
38	47		1,085	6	Black shale
37	5		1,090	6	Thin-bedded dark gray limestone
36	25		1,116	6	Thin sandstone and black shale
35	21		1,137	6	Gray-black shale
34	83		1,220	6	Anhydrite with local conglomerate at base 0-2 feet in thickness. Anhydrite probably not more than 60 feet in thickness, but slumping is so bad that this could not be determined
33	5		1,225	6	Thin conglomeratic limestone and black shale
32	52		1,277	6	Gray-greenish thin-bedded sandstone
31	15	6	1,293		Covered slope
30	10		1,303		Coarse greenish sandstone
29	15		1,318		Covered slope
28	26		1,344		Massive blocky coarse conglomeratic sandstone
27	36		1,380		Covered slope
26	5		1,385		Coarse gray-green cross-bedded sandstone
25	160		1,545		Covered slope, probably mostly shale
24	36		1,581		Conglomeratic sandstone, not so massive
23	8		1,589		Sandy dark gray shale
22	15	6	1,604	6	Black blocky limestone and black shale
21	36		1,640	6	Buff massive conglomeratic sandstone
20	5		1,645	6	Black limestone
19	30		1,675	6	Cross-bedded gray-green shale
18	4		1,679	6	Sandy dark gray shale
17	5		1,684	6	Sandy limestone
16	11		1,695	6	Black micaceous shale and sandstone shells
15	41		1,736	6	Gray coarse massive sandstone, cliff-former
14	5		1,741	6	Micaceous black shale and limestone shells
13	3		1,744	6	Dark gray dense limestone
12	21		1,765	6	Conglomeratic sandstone
11	15		1,780	6	Micaceous black shale with limestone shells at top
10	3		1,783	6	Yellow rubbly limestone
9	41		1,824	6	Micaceous dark maroon and gray shale
8	52		1,876	6	Massive coarse sandstone
7	50		1,926	6	Dark gray shale and dark gray limestone shells some conglomeratic
6	8		1,934	6	Coarse sandstone
5	40		1,974	6	Gray-to-black shale with thin shells of limestone and sandstone
4	22		1,996	6	Dark gray, blocky limestone, cubical fracture
3	21		2,017	6	Covered slope
2	5		2,022	6	Hard sandy limestone
1	124		2,146	6	Covered slope, probably mostly shale, conglomeratic at base, composed of boulders of Ouray limestone

Unconformity

OURAY LIMESTONE DEVONIAN

Since the work by Spencer and Girty, much has been learned concerning the range and distribution of the fossils described by them. From the fossils mentioned it is now known that the Hermosa is early Des Moines or Cherokee in age and is not Missourian as suggested by Spencer. In comparing the fossils listed by Spencer with the published descriptions and figures given by Girty,[2] and then comparing these with the recent work by Dunbar and Condra,[3] the correct identification is found to be as follows and proves the age of the Hermosa to be not younger than Cherokee.

Spencer's Identification	*Dunbar's Identification*
Productus semireticulatus	*Dictyoclostus hermosanus* (Girty)
Productus nebraskensis	*Juresania symmetrica* (McChesney)
Productus cora	*Linoproductus* sp.
Spirifer cameratus	*Neospirifer cameratus?*
Chonetes mesolobus	*Mesolobus mesolobus* cf. var. *decipiens* (Girty)

Three other species mentioned by Girty as occurring in the Hermosa are: *Spirifer boonensis* (now equals *S. occidentalis* Girty); *S. rockymontanus*, and *Marginifera haydenensis*. Of these, *S. occidentalis* has its highest occurrence in the Fort Scott, Des Moines of the Mid-Continent Pennsylvanian. *S. rockymontanus* never occurs above the Cherokee. *M. haydenensis* is present in the basal Pennsylvanian (Springer) of the Ardmore basin, Oklahoma, but has never been found above the Cherokee. *Prismopora* is widely distributed in the lower part of the Des Moines series and has never been found in higher beds. It is characteristic of the lower part of the Pennsylvanian all the way from Texas to Illinois and has been cited by Savage as one of the guide fossils of the lower part of the Illinois section. *Chaetetes* is just as important as *Prismopora* as a guide fossil for these same beds.

The *Fusulina cylindrica* mentioned by Spencer is now known to cover at least two distinct genera: *Fusulina* and *Wedekindellina*[4]. Of these two genera, *Wedekindellina* and all of its species are not known to occur above the Cherokee anywhere in the Pennsylvanian beds of the Mid-Continent. The genus *Fusulina* is not known to occur above the Des Moines of the Mid-Continent. There are several species of *Fusulina* which occur in the upper Des Moines or Marmaton; however, all of the species listed in the type section are of Cherokee age.

A comparison of the fauna of the Hermosa formation with that of the McCoy formation shows them to be identical and therefore equivalent in age.

ROBERT ROTH

WICHITA FALLS, TEXAS

[2] *U. S. Geol. Survey Prof. Paper 16.*

[3] Carl O. Dunbar and G. E. Condra, "Brachiopoda of the Pennsylvanian System in Nebraska." *Nebraska Geol. Survey Bull. 5*, 2d Ser. (1932).

[4] Carl O. Dunbar and Lloyd G. Henbest, "The Fusulinid Genera Fusulina, Fusulinella and Wedekindella." *Amer. Jour. Sci.*, Vol. 20 (November, 1930).

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 948-959, 4 FIGS.

DISCUSSION

(With additional information)

LISSIE FORMATION AND BEAUMONT CLAY IN SOUTH TEXAS

The following remarks are intended as an elaboration and a review of the description of these Pleistocene formations by F. B. Plummer, pp. 780–95, of Vol. I, "Stratigraphy," of "The Geology of Texas," by E. H. Sellards, W. S. Adkins, and F. B. Plummer, issued as *University of Texas Bull. 3232*, under date of August 22, 1932.[1] Plummer's contribution, Part 3, "Cenozoic Systems in Texas," as is the case with the rest of the volume, is excellently written, bringing together available information, including the work of many geologists, much of it unpublished, in a comprehensive manner and showing a broad grasp of the problems involved. The result, although partly a compilation, has the freshness of an original contribution and shows the evidences of careful work by the author, which must have included much field work. Our knowledge of these formations is much improved by this volume.[2]

The discussion will follow the page order of *Bulletin 3232* and will include notice of a few minor errors and omissions in that text. The main object of the discussion is to add to Plummer's description of the Beaumont clay—which is based chiefly on the area north of Guadalupe River—some data on it from the coast prairie south of the Guadalupe, including that portion placed in the "Rio Grande Plain" of the zoölogists, botanists, and soil scientists.[3]

A few remarks only on the Lissie are included, the writer being less familiar with its outcrop area than he is with that of the Beaumont.

It should be noted that the mapping of the contact between the Lissie and Beaumont presents some problems difficult of solution, in that exposures for the zoning of the two are inadequate, that clay of Beaumont type occurs in beds in the Lissie and that sands similar to some which occur in the Lissie are found also in the Beaumont—at least so far as a macroscopic examination reveals—and because of outwash of Lissie material upon the Beaumont by both ancient and recent streams, in addition to such offsets of the contact line as may be occasioned by diastrophic ("structural") deformation.

LISSIE FORMATION

Page 785, footnote 266.—

Caliche, according to W. A. Price, is found under 12 inches of soil in western Hidalgo County and has been encountered in core tests in the Saxet gas field, Nueces County, at depths between 85 and 100 feet. This latter occurrence may be the base of the Lissie.

Caliche in Hidalgo County of Lissie and Beaumont age occurs beneath the soil in beds and lenses at depths ranging from 3 to 12 feet (not inches). The minimum reported depth for such caliche in the Saxet field of Nueces

[1] The writer's copy was received in 1933, after the manuscripts of his papers here cited had gone to press.

[2] See review by Owen, this *Bulletin*, Vol. 18, No. 4 (April, 1934), p. 556.

[3] W. T. Carter, "The Soils of Texas," *Texas Agr. Exp. Sta. Bull. 431* (1931). 192 pp., 90 figs., map.

County ranges from 35 to 100 feet in different wells, as logged by drillers. The reported differences in depth may be due to errors in logging, to dip, or to faulting. Getzendaner has shown apparent faulting at the horizon of the *Discorbis* marine zone in this field.[4] If this caliche is older than Beaumont, the top of the Lissie would be the more likely postulate.

Page 786. Topography of Lissie and Beaumont.—

The outcrop of the Lissie is a nearly featureless plain bounded on the north by a ridge known as the Hockley escarpment. Streams meander broadly across this flat belt in broad, shallow valleys bordered by a slight ridge of sand deposited as a natural levee. The outcrop of the Goliad and the upper Pliocene sands have more maturely dissected rolling uplands and normal stream profiles.

Page 792.—Among the distinguishing characteristics are listed:

Flat, featureless surface. The surface of the Beaumont is a flat, featureless, treeless plain undissected by broad valleys. The streams, except the large rivers, flow in narrow channels bordered with sand and silt built up slightly above the plain surface. In all clay formations north of the Beaumont the main streams have broad valleys.

Some streams are entrenched through the Lissie outcrop area and are not now building natural levees upon the upland prairie. Natural levees of ancient streams can be more readily traced upon the Beaumont, where they consist of sandy materials in contrast to the clay of the plain, than they can upon the sandy sediments of the Lissie, where there is no such sharp lithologic contrast. Reworking of sand into dunes also tends to obscure the ancient levees.

During the past 20–40 years a heavy mesquite forest has covered most of the Beaumont and Lissie outcrop areas in South Texas.

The contact of the Lissie with the Beaumont in South Texas is marked, in many places, by a low topographic scarp, perhaps 15 feet high, the Lissie outcrop area showing a low rolling topography (not wholly flat). Plummer's remarks as to the flatness of these formations apply strictly to the Beaumont which has a slope of about 2.5 feet per mile and almost no visible relief except in the immediate vicinity of modern stream valleys and of the natural levees of ancient streams. Both formations, however, present a very much flatter aspect than that of the Goliad on the west. The Lissie-Beaumont contact scarp may be noted between Banquette and Orange Grove, in Nueces County.[5]

The color of the Lissie is given by Plummer as follows.

Page 786.—The Lissie is distinctly red, orange red, or pinkish buff. The Goliad and upper Citronelle sands are grayish buff and have in most places much lighter shades than the Lissie.

He states that he thinks of *buff* as the color of a buff cochin hen. The word *buff* has been used by geologists for so many shades that it has almost ceased to have a meaning and has been abandoned by some governmental surveys. Webster gives it as "a saddened yellowish orange." It has been used in publication for all shades of brownish yellow, olive-drab, yellowish orange, yellowish gray, and even for some shades of blue.

[4] A. E. Getzendaner, "McFaddin-O'Conner, Greta, Fox, Refugio, White Point, and Saxet Fields," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 4 (April, 1934), pp. 519–30. Getzendaner has read this discussion and the writer's thanks are due him.

[5] On the Orange Grove road, 2 miles west of its junction with the Banquette-Bluntzer road, is a typical exposure of this scarp.

Page 787.—In the list of fossil vertebrates from Lissie beds the species from Locality 1, "2 feet above base of gravel at Loma de la Cruz, Mexico, 3 miles east of Rio Grande City, Starr County," is omitted. Bailey reports the specimens as determined by Wortman to be *Equus.* cf. *E. fraternus.*[6]

BEAUMONT CLAY

Page 788.—A study of water sands in coastal formations reveals what appears to be a surprising flatness of dip of the Beaumont. While formations

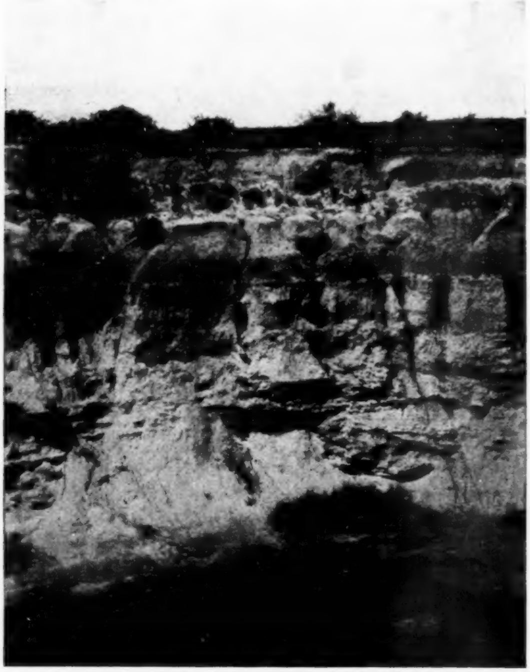

FIG. 1.—Crater wall of White Point Oil and Gas Company's Rachal No. 2 well (White Point Development Company fee), showing clay and caliche above cross-bedded sand. Water issues with hydrogen sulphide gas from crater floor. Contact line one-third depth from top of section may be Lissie—Recent contact. White Point field, Nueces County, Texas.

interior to it show dips steadily increasing seaward as we pass from formation to formation, the Beaumont seems to have flat dip and not to exceed 400 feet in thickness, holding this dimension from near its western extremity to

[6] T. L. Bailey, "The Gueydan, a New Middle Tertiary Formation from the Southwestern Coastal Plain of Texas," *Univ. Texas Bull. 2645.* 187 pp., 3 figs., 12 pls. (incl. map), 1926 (1927).

the coast. This apparent flat dip is revealed in a few cross sections made near Corpus Christi by geologists for an oil company.

If this apparent flattening of the dip across the Beaumont outcrop truly represents the formation in this portion of South Texas, then the Lissie lies close enough to the surface to be brought up by local deformation, including faulting, and it may be correct to assign such sandy surface sections as that of White Point, and such shallow caliche beds as those of the Saxet field to the Lissie. At White Point a 50-foot section in a gas-well crater shows clay above sand containing ostracods. The upper clay may be river alluvium and the sand, Lissie (Fig. 1). The caliche is a local lens in the clay. At Angelita,

FIG. 2.—Caliche concretions in red and green Beaumont clay at Red Bluff, west shore of Galveston Bay, Harris County, Texas. Erosional surface midway of bluff shows outcropping concretions and two calcium carbonate cylinders on bluff face which have not fallen out.

where Adkins and O'Neill have opened a new pool near Odem, San Patricio County, a gravel-bearing sandstone and other sands without gravel crop out and indicate a Lissie inlier in the Beaumont. Caliche at 60 feet in the Agua Dulce field is older than Beaumont, as this area lies almost on the normal position of the Lissie-Beaumont contact.

Sand is, however, a prominent component of the Beaumont in South Texas. Lenses of sand are found in augur holes between Oso Creek, Neuces County, and Aransas River, San Patricio County. The top of this sand bed or beds lies 15–35 feet below the surface. Much sand is seen in the bluffs at Corpus Christi, in the Beaumont outcrop area.

Plummer's statements, which follow, reflect the usual conception of the Beaumont, which may be correct in large areas:

Page 788.—It (the Beaumont) consists of 400 to 900 feet of clay and marl interbedded with lentils of clay between the Lissie formation and surface silts, surface terrace, and alluvial deposits. . . . It dips southeastward and extends beneath beach sand and waters of the Gulf as far as the continental shelf. Its thickness is fairly uniform, ranging from 450 to 900 feet with an average of about 700 feet.

Page 791.—The clay is bluish gray, yellowish gray, pinkish gray, purple, and some shades of red. It is in most places calcareous in composition and contains calcareous nodules, rarely calcareous concretions, and fragments of more or less decomposed wood. In most places the clay is highly colloidal, and when wet forms a thick, very sticky mud difficult to traverse with car or wagon in the rainy season. These clays are characterized by their low content of lime and comparatively high silica content. The analyses undoubtedly represent the nonmarine portion of the Beaumont clay. Other deposits, particularly some of those containing oyster beds, have a higher percentage of lime.

Colors of the clay of the Beaumont, besides those given, include yellowish green, green, and much tan clay which bears abundant flakes and crystals of selenite. The selenite is quite characteristic of the formation in South Texas. Blood-red and brick-red color is rare or absent south of Guadalupe River and Lavaca Bay. Selenite occurs as far north, at least, as Galveston Bay, northeast of which the writer is not familiar with the details of the formation. This deep red color[7] seems to have been an original depositional feature in the Brazos-Colorado delta sediments, from Lavaca Bay to Galveston Bay.

All exposures of Beaumont seen by the writer in Texas prominently exhibit features produced by weathering and soil reactions. The leaching of the upper zone of the soil of its lime and the deposition of the several forms of calcareous caliche[8] have produced changes in the original sediments. Hence, the writer is strongly of the opinion that the Beaumont *outcrop* should be viewed in the light of the soil reports of the U. S. Bureau of Chemistry and Soils.

A pinkish yellow or pinkish brown layer high in calcium carbonate is formed in many soils at 12–24 inches below the surface and is described in detail for each soil in the soil reports. Small calcium carbonate nodules are scattered through nearly all sections to depths of at least 40 feet. Many exposures of the clay, both the deep red and the lighter clays, contain large caliche concretions. These may be in the form of balls the size of oranges (as in the bank of Navidad River a short distance north of the Southern Pacific Railroad bridge east of Edna, Jackson County), or in vertical cylinders as thick as sweet potatoes (as at Red Bluff, on the west shore of Galveston Bay, Harris County, and in pale tan clay on the south shore of Nueces Bay near mouth of Oso Creek). Associated with the vertical cylinders is a marked physical and chemical alteration of the clay which proceeds from centers of

[7] J. Frank Dobie, "Legends of Texas" (1924), *Pub. Texas Folk Lore Soc.*, No. III, 2d. ed. (Austin, Texas, 1924), p. 216, shows that there seems to have been a confusion in the days of the Spanish explorers, in their attempt to follow Indian usage, as to which river, the present Colorado or the present Brazos, should receive the name "red" (Colorado). The Brazos and some creek or bayou emptying near it were named "The arms of God"—"Los brazos de Dios"—by a Spanish explorer.

[8] H. W. Hawker, "A Study of the Soils of Hidalgo County, Texas, and the Stages of Their Soil-Lime Accumulation," *Soil Science*, Vol. 23, No. 6 (June, 1927), pp. 475–85; 1 pl., 1 fig.

W. Armstrong Price, "Reynosa Problem of South Texas and Origin of Caliche," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 5 (May, 1933), pp. 488–522; 5 figs.

much induced tubular porosity outward toward centers of less porosity. Downward drainage is the cause of the tubular porosity.

The centers of maximum vertical drainage show innumerable, closely placed, vertical, somewhat wandering, hair-sized tubules which join so abundantly at the center points that the clay becomes honeycombed. These centers show much green clay and are evidently centers of reduction of the iron oxides by descending soil reagents. These centers do not seem to be related in any way to former root channels, being gradually developed through horizontal distances ranging from a few inches to a foot and being very abundant and, in places, somewhat evenly spaced. In the lower parts of the greenish, canal-like centers, calcium carbonate begins to be accumulated

FIG. 3.—Cylindrical masses of green clay in red Beaumont clay at Red Bluff Harris County, Texas. Some calcium carbonate occurs with green clay which represents incipient cylindrical concretions. Horizontal contact of light and dark bands seems to represent an original Beaumont surface under flank of distributory ridge of sandy loam. Reduction of red Beaumont has progressed more rapidly just under this contact than it has deeper in clay. Original print shows fine vertical tubules with light-colored walls through which soil solutions and grains of sand and flakes of clay descend.

and increases in amount downward, finally forming dense cylinders more or less wrapped around with thin greenish clay layers. In some instances the green clay extends with little visible calcium carbonate, to water level. The centers of the red clay most remote from the green clay-caliche centers are duller red and more compact than the general body of the red clay (Figs. 2 and 3).

Similar vertical cylinders of caliche, but, where the writer has seen them, slenderer, more numerous and more closely spaced, are characteristic of many

exposures of the calcareous Lagarto clays of the type locality and its vicinity.

A process of soil change which accompanies the development of the vertical tubules in these clay soils is *eluviation*, a mechanical process by which coarse particles, such as sand, become transported downward through the finer, clay-like, particles of a sandy clay. This process may be observed in operation in the exposures noted. The lower parts of the soil section ("soil column" or "soil profile" of the soil reports) is usually denser and more clayey than the upper zones.

Toward the middle of the Beaumont outcrop area, within a few feet of the surface, occur a number of isolated lenses of caliche, slightly less indurated

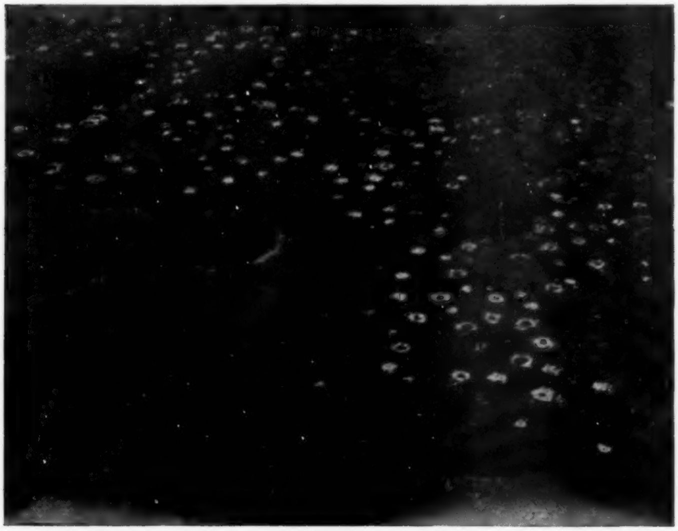

FIG. 4.—Air view of pimple mounds on sandy ridge of an ancient distributary of Brazos River between Freeport and Pierce Junction, Texas. Lateral drainage lines show as dark, sinuous bands.

than that of the Goliad (Reynosa) area. These small lenses have been quarried for road material for very local use. It is not determined whether they are indigenous to the Beaumont or represent uplifted Lissie. The soil beneath coastal playas shows high concentrations of caliche nodules. These, in places, approach beds of consolidated caliche in form, but their nodular character is apparent.

Page 792.—Pimple prairies are uncommon in South Texas. Plummer says:

Pimple prairies. Small knolls 10 to 25 feet in diameter and 1 to 4 feet high occur in clusters or belts over the flat surface of the Beaumont plain in certain areas where patches of silt occur. These pimple-like knolls are especially common along the sandy belts produced by minor levees of former temporary streams. They occur also on the Lissie formation and on other silty formations in east Texas and Louisiana. They are

especially noticeable, however, on the Beaumont plain, where any slight elevation is noticeable in contrast to the generally featureless surface. These knolls were formed by the action of wind at a time when the soil was not fixed by so heavy a vegetation as at present and are thought to be ancient, small dunes now nearly obliterated by weathering and erosion. They are composed of silt and superimposed on an old soil line of clay or hard, silty clay. Veatch and others have discussed the origin of these interesting features in much detail.

They occur along the lee sides of offshore bars, including a bar now on the mainland,[9] but have not been noted by the writer along the sandy distributaries of South Texas rivers, although no comprehensive search for them has been made (Fig. 4). Clyde T. Reed, biologist, of Kingsville, Texas, reports[10] that he has observed pimple mounds along the offshore bar forming as mounds of residual sand held by plant roots in spots where vegetation is establishing itself on fresh surfaces of sand.

Page 792.—Plummer's description of the soils of the Beaumont and Lissie:

> Soils. The surface soil derived from the Beaumont is typically dark, heavy clay soil, exceedingly sticky when wet and hard when dry and known as the Lake Charles soil. The soil of the Lissie formation below and recent silts above are light silt loams.

applies to the central and northeastern parts of the coastal plain. South of Guadalupe[11] River Beaumont soils have been mapped as Victoria clay (Vc). Distributary ridges on the Beaumont are mapped either as Edna fine sandy loam (Es) or Edna loam (El) where they are closely joined to Lissie areas and as Victoria loam (Vl) where the sandy ridges are remote from the Lissie source material. Dune-like parts of the distributary deposits are mapped as Victoria fine sandy loam (Vs).

Pages 793–794.—Plummer says (Paragraph 6, p. 793):

> Invertebrate fossils. The Beaumont clay contains in a few places near the coast oyster and clam shells and rarely a shell bed made up of large numbers of *Ostrea virginica* Gmelin and *Rangea cuneata* (Gray).
>
> Also (p. 794): *Ostrea virginica* Gmelin occurs . . . both singly and in beds . . . [which] can be traced in some places for several miles . . . [but] are rare in Texas.

Besides these two pelecypods and elephants, mammoths, and horses, Plummer gives a list of between 30 and 40 molluscs (p. 794). To these occurrences should be added the foraminiferal fauna indigenous to the Beaumont of South Texas. The following list is of species of *Foraminifera* taken from augur cuttings obtained by the writer from localities within the tidewater section of the Beaumont in Nueces and San Patricio counties. The determinations were made by several paleontologists, including Alva C. Ellisor, who recently corrected the synonymy.

[9] W. Armstrong Price, "Rôle of Diastrophism in Topography of Corpus Christi Area, South Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 8 (August, 1933), pp. 907–62; 17 figs.

[10] Oral communication.

[11] W. M. Davis has somewhere shown that there is an interesting history in names with the prefix *Guada*. This is a Spanish form of a North African word commonly Anglicised to *waddy*, a dry-country stream bed. The Spanish equivalent is *arroyo*, common to the Southwest, but the Spanish form of the African word came to semi-arid South Texas *via* semi-arid Spain to which it was taken by the Moors. The *gu* in *Guadalupe* is pronounced *w*, and the final *e* is sounded.

Elphidium discoidale (d'Orbigny)
Elphidium incertum (Williamson) var. *mexicanum* Kornfeld
Elphidium gunteri Cole var. *galvestonensis* Kornfeld
Nonion depressula (Walker and Jacob) var. *matagordana* Kornfeld
Quinqueloculina seminula (Linné)
Rotalia beccarii (Linné) var. *tepida* Cushman
Rotalia beccarii (Linné) var. *ornata* Cushman

To these should be added the common Beaumont form, not noted in the augur cuttings:

Ammobaculites agglutinans (d'Orbigny).

These *Foraminifera* from the augur holes occur with large molluscs, and alone, in yellowish tan shell marl and also in other clays. Reworked Cretaceous *Foraminifera* also occur in the Beaumont.

A light gray, calcareous clay exposed in a drainage ditch 3 miles east of the town of Taft, San Patricio County, yielded fragments of bones and of elephant teeth which seemed to be smaller than those of typical *Elephas imperator* Leidy and are possibly from *Elephas columbi* Falconer.

Plummer cites (pp. 793–4) the description by the archaeologist, Pearce, of reefs of reworked *Rangea cuneata* (Gray) found at river mouths, in bay heads and along lake bluffs. These shells, according to Pearce, have been eroded from [Beaumont?] silt and clay and concentrated into reefs or piles 3–15 feet thick and 30–75 feet in lateral extent. He believes them to have been formed by combined river and wave action, because found with their long axes parallel with river courses. He does not think they are ordinary beach ridges. The Indian camp débris commonly found in and on them Pearce thinks is of later origin than the shell ridges, the Indians merely occupying them as temporary camp sites, in spite of the fact that the edible *Rangea* is known to have been eaten by the Indians. These reefs are listed from the Neches and Sabine rivers, from Trinity Bay, from along San Jacinto River and the bluffs of Black Lake, near Hackberry Island, Cameron Parish, Louisiana. *Rangea cuneata* (Gray) also occurs abundantly scattered through the Beaumont of Texas, where it is obtained in almost every well drilled into the formation in the Houston-Beaumont district and in many other areas.

In the examination of shell heaps there arises the question as to whether surficial shell heaps of prehistoric age containing Indian relics and burials are accumulations of Indian camp débris or whether this débris has merely been deposited upon them, washed down into the porous shell heaps, and buried in them in holes dug to receive refuse. The problem still arises even where the shell has been extensively slaked and blackened by fire.

In the case of certain abundant piles of the shells of oysters and other edible mollusca in South Texas tidewater areas, this problem of Indian origin or late occupation has been given a different answer from that of Pearce to the occurrence of piles and reefs of *Rangea* farther north.

There are in South Texas very abundant heaps of oyster and other mollusc shells, almost entirely of edible species, scattered all along the bluffs of the present lagoons, bays, and estuaries in sight of open water, or in sight of swampy flats of floodplain-and-delta origin formed in the heads of bays and estuaries in late recent time. The restriction of these shell heaps, with very rare exceptions, to such shore-bluff locations removes them from the class of river-current-and-bay-wave reefs which is described by Pearce. Their

constant association with Indian camp débris, thoroughly mixed in the heaps at all levels, indicates their Indian origin. They have been referred to the shore-dwelling tribes, those south of Galveston Bay having been left by the Karankawas[12] who lived along the shores in historic time and who were known by early settlers to have been a fish-and-shell-fish-eating tribe. The writer has recently discussed these shore-bluff shell accumulations, giving references to the work of the archaeologists Gatschett and Martin.[13] These shell accumulations lie both near the present water level, below water where bluffs have been eroded, and on bluffs which stand well above the Ingleside Terrace, the only marine terrace of late Pleistocene or early recent origin so far recognized in South Texas north of Rio Grande Delta. These shell heaps are found in the upper soil levels and on the surface of the ground. They are sharply distinguished from beds of shells of Beaumont age, which have been deposited *in situ* in water, by the absence of the marly, foraminiferal clay matrix which encloses shell beds of marine or lagoonal origin in the Beaumont where these have been identified by the writer. Shell reefs of the type described by Pearce have not been identified by the writer on the land in South Texas.

Lenses of coquina containing oysters and other pelecypod shells and calcified *Foraminifera* (swelled during development of calcite) with sand, fine gravel, and selenite crystals occur in the Beaumont at shallow depths along the west side of Copano Bay and west of Mission Bay. They were not deposited at the present bay level and are probably older than the Ingleside Terrace lagoon.

One such lens crops out in the west edge of the town lots of the village of Bayside, Refugio County, on Quarry Run, a northside tributary of Aransas River. It may be called the *Bayside coquina*. It was quarried for paving blocks, foundation stone, and chimneys for the once populous towns of St. Mary's and Bayside on the west shore of Copano Bay. The thickness of the bed is possibly as much as 10 feet, thinning westward. This lens seems to extend possibly 4–6 miles in a northeasterly direction and 1–3 miles westward. A similar lens occurs at Hines Spring, an early ranch settlement, now deserted, on the north bank of Mission River west of Mission Bay in Refugio County. It is of the same age as the Bayside coquina and may be referred to as the Hines Spring coquina.

Plummer states that indigenous oyster beds ("from six inches to a foot in thickness") are rare in the Beaumont in Texas, but the writer finds them to be common in Refugio County down to a depth of at least 100 feet, as reported in water wells and as penetrated in holes bored to this depth for the writer a few miles west of Bayside. They are also reported at several levels down to 575 feet in the log of a well drilled at the south shore of Corpus Christi bay at the mouth of Oso Creek.

Page 795.—The calcareous clays of the Beaumont typically weather to a deep black soil, which is 4.5–5 feet deep in the Corpus Christi area. Sandy distributary ridges on the Beaumont clays have a mottled yellow-to-red-and-brown soil and are apt to have a brush cover. The large area of "blackland" Beaumont soil (Victoria clay) covering most of several counties and centering west of Corpus Christi produces a very large amount of cotton of finest grade

[12] Spanish form is *Carancahua*.

[13] W. Armstrong Price, *op. cit.*

and is the center of the most highly mechanized farming of coastal Texas. Cotton grown on the Beaumont has made up perhaps a third of the export cotton which has passed through the port of Corpus Christi. The Beaumont blackland (Victoria clay soil) produces cotton of a more uniform grade and staple than the other soils of South Texas and probably has a larger potential yield in cotton per acre than soils developed on other formations of the region.

It has been pointed out by the writer[14] that the Beaumont has been deeply trenched by rivers during a period of recession of the Gulf shoreline with silting up of the channels and that the seaward margin of the Beaumont to-day is cut by the Ingleside Terrace (marked by Lomalta soils) with deposition of terrace sediments and of a former offshore sand bar which has retreated to shore (mature offshore bar). Recent sediments lie in the coastal lagoon back of the present (young) offshore bar and in bay basins cut out of the Beaumont by wave planation. These basins contain coquina, large masses of rose-colored-to-red-brown selenite and gypsum, and manganese deposits (bog manganese and wad). Hence, recent sediments of the gulf and bays unconformably overlie the Beaumont in South Texas.

Study of former beach levels along the edge of the Beaumont in the active delta of the Rio Grande must take into consideration compaction of such areas of the delta as are not being renewed by overflow and growth of distributary ridges.[15] The writer has hesitated to select from the topographic maps[16] correlatives of the Ingleside Terrace in the Rio Grande Delta, although large areas of its diagnostic soils (Lomalta series) mapped on flats marginal to the present lagoons may include a terrace of Ingleside age. Ground study is needed before such correlation is made.

PLEISTOCENE CLIMATES

Pages 784–785.—Plummer has cited the widespread alluvial apron of sand and gravel of Lissie age which spread gulfward from the Sierra Madre of northern Mexico and the mountains of New Mexico and West Texas and contained much coarse material. Barton has also shown[17] that there was a Pleistocene period of large river-meander loops in contrast with the loops of smaller radius along the same streams of to-day. Both writers have interpreted these data as indicating a period of greatly increased rainfall in the Pleistocene, Barton's meanders suggesting to him late Pleistocene and early recent time.

Reed[18] has shown that a loose deposit of striated slabs and angular boulders of Eocene, Cretaceous, and Paleozoic rocks, 50–250 miles from their outcrops, form a shoal in Brazos River in the present bed and for 10 feet above water. He interprets this deposit as accumulated by an ice jam. The age would seem to be recent.

Plummer correlated the period of increased rainfall with the advance and

[14] *Op. cit.*

[15] A. C. Trowbridge, "Building of Mississippi Delta," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 7 (July, 1933), pp. 867–901; 14 figs.

[16] Advance sheets, *U. S. Geol. Survey*, 7′30″ quadrangle sheets of Cameron County, Texas, with 1-foot contours.

[17] D. C. Barton, "Deltaic Coastal Plain of Southeastern Texas," *Bull. Geol. Soc. Amer.*, Vol. 41 (September 30, 1930), pp. 381–82.

[18] L. C. Reed, "Possible Evidence of Pleistocene Ice Action in Southeast Texas," *Amer. Jour. Sci.*, Vol. 15 (June, 1928), pp. 520–21.

retreat of the ice sheet of northern latitudes, but Antevs[19] points out, from his long and detailed studies of world climate and Pleistocene climatic evidences, that:

> The drop in temperature and the gradually increasing anticyclones above the ice sheets greatly changed meteorological conditions also in far distant regions. The climax of these changes was naturally reached at about the time of the maximum extent of the ice. In the unglaciated regions the climax may have occurred simultaneously with the great climatic change that put an end to the growth of the ice sheets. This is probable because abnormally great precipitation could not well occur at the same time over the ice sheets and in other regions of the globe on account of the low temperature and consequently not exceptional evaporation. The decrease in precipitation that now began over the ice sheets was correlated with an increase in rainfall in the belts extending equatorward from the ice caps. Because of this and because of less evaporation due to lower temperature, the greater part, the polar part, of the modern arid and semi-arid belts . . . enjoyed moister conditions than they do today. This is shown by evidence of various kinds, among which the former vast extension of bodies of water, the great watercourses now dry, and fossil occurrence and present distribution of plants and animals are the most important.

The writer has suggested[20] that there was an alternation of semi-arid climatic periods in South Texas which may have been marked by the development at each period of beds of caliche on the coastal plain where soil was developed on calcareous sediments without too rapid erosion. These semi-arid periods in a subtropical latitude seem correlative with periods of maximum precipitation in the polar ice-cap regions. Ice advance for each period began with and closely followed the initiation of increasing precipitation, lag occurring due to the slowness of ice movement.

If glacial control of southern climates is to be expected, as Antevs believes, we should look for alternations of periods of maximum run-off (high precipitation and low evaporation, concurrently) with periods of semi-aridity in South Texas. Since lime-accumulating soils are characteristic of semi-arid regions and non-lime accumulating soils (which accumulate the sesquioxides of iron, aluminum, manganese, et cetera) are characteristic of humid regions, all in non-polar climates, we may be able to work out a climatic sequence in the Pleistocene and recent alluvial deposits of the Texas Coastal Plain, where ancient soils and soil minerals are preserved.

Studies of hurricane development and movement suggest that it would not require more than a relatively slight increase in the amount of summer insolation over the Atlantic off western equatorial Africa to produce many more hurricanes and more severe ones than those which have visited the western Gulf of Mexico during the Weather Bureau record period of a half-century. These hurricanes hurl tremendous quantities of water against such mountain fronts as that of the eastern Sierra Madre of Mexico, where it is precipitated, resulting in great floods in coastal plain rivers. Thus, in occasional grc torms we have an agency possibly more strongly operative in the past which could have transported the gravels of the Lissie-Reynosa-Goliad. If the occasional great storms varied in maximum intensity in the past, they were probably accompanied by similar general weather changes.

W. Armstrong Price

Corpus Christi, Texas
March 30, 1934

[19] Ernst Antevs, "The Last Glaciation," *Amer. Geogr. Soc. Research Ser. 17* (New York, 1928), p. 32.

[20] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 5 (May, 1933), p. 516.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 960-962

REVIEWS AND NEW PUBLICATIONS

Outlines of Physical Geology. By CHESTER R. LONGWELL, ADOLPH KNOPF, and RICHARD F. FLINT. John Wiley and Sons, New York (1934). 356 pp., 297 figs. 6×9 inches. Cloth. Price net, $3.00.

The field of physical geology, as presented in the average college course, is of necessity somewhat standardized. Furthermore, in the last few years so many texts on the subject have appeared that the only possible excuse for a new one is some obvious superiority in the method of approach. Whether any particular book meets this important demand rests in part, certainly, on the character of the course for which the text has been prepared. Beyond this consideration, the personal experience and natural bias of the reviewer will almost entirely control his reactions to the character of the volume.

From a fairly wide range of teaching experience, involving, at the one extreme, classes consisting wholly of women students taking the subject purely to meet a science requirement, and at the other, long contact with engineering students, the reviewer feels quite certain that most texts in physical geology would be greatly improved by numerous references to practical applications and useful aspects of the subject, so long as these are within the easy understanding of the students involved. Class interest in the subject seems, in all cases, to be intensified by an understanding of the way the facts of geology apply to the problems of everyday life about us. To the reviewer, it appears rather unfortunate that this text is peculiarly lacking in direct applications of geologic principles to such simple problems as those of highway construction, water supply, irrigation, harbor development, and countless others.

Again, it seems unfortunate that the various major subjects discussed are not more closely knit together. A few examples of what is meant by this criticism must suffice. The subject of weathering, for instance, could have been much more closely related to other processes, by pointing out clearly its part in freeing the lime from igneous rocks to be later incorporated into limestone; by showing how weathering commonly leaves a residual material of mixed sand and clay, and that wind and running water, in their later action, are the agents producing ultimate separation; by indicating in detail the relations of slope, forest cover, nature of the ground, rate of precipitation, and rate of evaporation to the relative amounts of ground water and run-off. Similarly the wide distribution of bentonite, now interpreted as volcanic ash, might well have been included under wind work, and its importance in correlation mentioned, to show the relation of the subject to historical geology, a relation which would scarcely even be guessed by the elementary student, but which would greatly enrich his view of the broader geologic principles. Numerous other illustrations could be pointed out of cases in which the whole field could have been much more intricately bound together by such treatment.

Throughout the work, many of the discussions seem too loosely circumscribed, and in places wholly inadequate. For instance, no person not already

familiar with the subject of the stages of the erosion cycle could, from the descriptions given, secure any definite idea as to where youth leaves off and maturity begins, or could really grasp the importance of the fact that the stages for a single valley and for a region as a whole are two distinct concepts, based on entirely separate and more or less independent conditions.

Many important items that are really necessary to a well-balanced discussion have been omitted. For example, considerable detail is presented (p. 42) regarding factors that might disturb the balance between erosion and deposition in a stream, but the effect of over-grazing and deforestation is ignored, though it is discussed in other relations (p. 59). The classification of lake basins (pp. 76–79) fails to include true marginal lakes, one shore of which is actually an ice dam, though this type is of great importance in our northern states. In the discussion of flood control (one of the few practical problems cited) a statement is made that straightening of the channel is a factor, but nothing is said about how such changes aid in flood control and no mention is made of utilizing old distributary channels as outlets for flood waters. In the discussion of the weathering of limestone by solution (p. 22), sand and clay are specifically mentioned as insoluble impurities, but no reference is made to chert, though it is a particularly conspicuous residue in many regions.

On the other hand, the book is very well written. The style is clear, concise, and interesting and the illustrations ample and of good grade. Controversial subjects, in general, are avoided or treated with an obvious effort toward fairness. Typographical errors are few and errors in statement even fewer.

The text is well suited for use in short elementary college courses, although it is the reviewer's feeling that even for such groups a closer knitting together of the various processes, and a more frequent reference to practical applications would have increased its efficiency. The weaknesses are chiefly those of omission rather than commission. It should be pointed out that the modifications which the reviewer has suggested could easily be included without any great increase in the length of the volume, and it is believed they would accomplish something worth while in increased interest and in coördinated understanding.

C. L. Dake

Rolla, Missouri
May 4, 1934

Petroleum Production Engineering. Oil Field Development (2d edit.). By Lester Charles Uren. 531 pp., 258 illus. 6×9 inches. McGraw-Hill Book Company, New York and London (1934). Cloth. Price, $5.00.

This is the first book of a two-volume revision and discusses the problems of petroleum engineering from prospecting to the completion of the well. This book endeavors to give a thorough outline of modern drilling and development practice. Each chapter is followed by a selected bibliography. The bibliographies cite 236 references by 228 authors.

A good idea of the contents of the book is given by the chapter headings, which are as follows: I. Properties, Occurrence, and Associations of Petroleum; II. Petroleum Exploration Methods; III. Acquisition of Title to Oil Lands; IV. Developing the Field; V. Drilling Equipment and Methods; General

Features; VI. Churn Drilling Equipment and Methods; VII. Rotary Drilling Equipment and Methods; VIII. Casing, Casing Appliances and Casing Methods; IX. Fishing Tools and Methods; X. Oil Field Hydrology; Exclusion of Water from Oil and Gas Wells; XI. Finishing the Well; and XII. Well Records.

The descriptions of modern equipment and field practice and the selected bibliographies of modern technical literature make this book very valuable as a text for students and as a reference volume for those engaged in oil field development.

LYNDON L. FOLEY

TULSA, OKLAHOMA
May 25, 1934

RECENT PUBLICATIONS

ARKANSAS AND OKLAHOMA

"The Origin and Age of the Boulder-Bearing Johns Valley Shale in the Ouachita Mountains of Arkansas and Oklahoma," by Raymond C. Moore. *Amer. Jour. Sci.* (New Haven, Connecticut), Vol. 27, No. 162 (June, 1934), pp. 432–53; 4 figs.

GENERAL

Tertiary Faunas. A text-book for oil-field paleontologists and students of geology. Vol. II, *The Sequence of Tertiary Faunas*, by A. Morley Davies. 252 pp., 28 figs., frontispiece. Outside dimensions, 8.75×5.75 inches. Demy 8 vo. Cloth. Thomas Murby and Company, 1 Fleet Lane, London, E. C. 4 (1934). Price, net, 15s.

Earth, Radio, and the Stars, by Harlan True Stetson. 336 pp., 88 figs., frontispiece in colors. Outside dimensions, 8.25×5.75 inches. Cloth. Whittlesey House, McGraw-Hill Book Company, 330 West 42d Street, New York (1934). Price, $3.00.

Oil and Petroleum Year Book 1934 (May, 1934), compiled by Walter E. Skinner. Twenty-fifth year of publication. lxv+352 pp., with inserted illustrated advertisements. Contains particulars of 673 English and foreign companies—producers, refiners, dealers, transporters, and oil finance companies, including principal American companies. Production statistics, glossary of technical terms, et cetera. Outside dimensions, 5.5×8.25 inches. Red cloth, Walter E. Skinner, 15 Dowgate Hill, Cannon Street, London, E. C. 4. Price. 7s. 6d., net; abroad, 8s. 6d., net, post free.

GERMANY

Deutsches Erdöl II (Petroleum in Germany, Vol. II), by August Moos, H. Steinbrecher, and O. Stutzer. Ninth volume in a series in the realm of the geology of fuels edited by Otto Stutzer. 98 pp., 8 illus. Outside dimensions, 10×6.75 inches. Paper. Ferdinand Enke, Stuttgart, W. (1934). Price, 9.80 RM.

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VOL. 18, NO. 7 (JULY, 1934), PP. 963-966

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Robert Tunstall Booth, San Antonio, Tex.
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C. C. Clark, W. F. Barbat, F. A. Menken
Robert Cecil Lane, Tyler, Tex.
J. S. Hudnall, G. W. Pirtle, F. H. Schouten
Claude Ervin Needham, Socorro, N. Mex.
Evan Just, W. C. Morse, F. B. Plummer
S. K. Van Steenbergh, East Bernard, Tex.
Louis A. Scholl, Jr., John C. Miller, F. C. Sealey
C. J. Ward, Orange, Tex.
E. W. Andrau, P. L. Vaudoit, Burr McWhirt

FOR ASSOCIATE MEMBERSHIP

Frederick Joseph Grimshaw, Detroit, Mich.
Lewis B. Kellum, R. L. Belknap, R. B. Newcombe
John Clifton Poole, Lafayette, La.
J. David Hedley, Herschel H. Cooper, D. R. Snow

FOR TRANSFER TO ACTIVE MEMBERSHIP

Robert Sala Breitenstein, Buenos Aires, Argentina, S. A.
John O. Bower, Carroll M. Wagner, George A. Severson
William Clarence Imbt, Urbana, Ill.
M. M. Leighton, Frank W. DeWolf, Alfred H. Bell
Clyde L. Wagner, Tulsa, Okla.
Chas. S. Lavington, E. A. Markley, Willard L. Miller

CODE OF ETHICS OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OBJECT. The object of this Association is to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and to encourage improvements in the methods of exploring for and exploiting these substances; to foster the spirit of scientific research amongst its members; to disseminate facts relating to the geology and technology of petroleum and natural gas; to maintain a high standard of professional conduct on the part of its members; and to protect the public from the work of inadequately trained and unscrupulous men posing as petroleum geologists. (Constitution, Article II.)

ARTICLE I. GENERAL PRINCIPLES

SECTION 1. The practice of petroleum geology is a profession. It is the duty of those engaged in it to be guided by the highest standards of professional conduct and to subordinate reward and financial gain thereto.

SEC. 2. The confidence of the public and of the oil industry can be won and held only by the practice of the highest ethical principles.

SEC. 3. Honesty, integrity, fairness, candor, fidelity to trust, inviolability of confidence, and conduct becoming a gentleman are incumbent upon every member of the Association.

ARTICLE II. RELATION OF GEOLOGIST TO PUBLIC AND PROFESSION

SECTION 1. A geologist should avoid and discourage sensational, exaggerated, and unwarranted statments, especially those that might induce participation in unsound enterprises.

SEC. 2 A geologist should not knowingly permit the publication of his reports or maps for the purpose of raising funds without legitimate and sound development in view.

SEC. 3. A geologist may accept for his services in the making of a report an interest in the property reported on, but it is desirable that the report state the fact of the existence of the interest.

SEC. 4. A geologist should not give an opinion or make a report without being as fully informed as might reasonably be expected, considering the purpose for which the information is desired. The opinion or report should make clear the conditions under which it is made.

SEC. 5. A geologist may publish simple and dignified business, professional, or announcement cards, but should not solicit business by other advertisements, or through agents, or by furnishing or inspiring exaggerated newspaper or magazine comment. The most worthy advertisement is a well-merited reputation for professional ability and fidelity. This cannot be forced, but must be the outcome of character and conduct.

ARTICLE III. RELATION OF GEOLOGIST TO EMPLOYER

SECTION 1. A geologist should protect, to the fullest extent possible, the interests of his employer so far as consistent with the public welfare and his professional obligations.

SEC. 2. A geologist who finds that his obligations to his employer conflict with his professional obligations should notify his employer of that fact. If the objectionable condition persists, the geologist should sever his connection with his employer.

SEC. 3. A geologist should not allow himself to become or remain identified with any enterprise of questionable character.

SEC. 4. A geologist should make known to his prospective employer any oil or gas interest which he holds in the region of his prospective employment.

SEC. 5. A geologist, while employed, should not directly or indirectly acquire any present or prospective oil or gas interest without the express consent of his employer.

SEC. 6. A geologist retained by one client, should, before accepting engagement by another, notify them of this affiliation, if in his opinion the interests might conflict.

SEC. 7. A geologist who has made an investigation for a client should not, without the client's consent, seek to profit from the economic information thus gained, or report on the same subject for another client, until the original client has had full opportunity to act on the report.

SEC. 8. A geologist should not accept direct or indirect compensation from both buyer and seller, without consent of both parties; or from parties dealing with his employer without the employer's consent.

SEC. 9. A geologist should observe scrupulously the rules, customs, and traditions of his employer as to the use or giving out of information or the acquisition of interests, both while employed and thereafter; and, except as permitted by such rules, customs and traditions or by the consent of the employer he should not seek to profit directly or indirectly from the economic information gained while so employed.

SEC. 10. A geologist employed by a state geological survey should not permit private professional work on the holding of private mineral interests in the state to interfere with his duty to the public or to lessen the confidence of the public in the survey. The preferable course is to avoid such private work and interests.

SEC. 11. A geologist should not divulge information given him in confidence.

ARTICLE IV. RELATION OF GEOLOGIST TO OTHER GEOLOGISTS

SECTION 1. A geologist should not falsely or maliciously attempt to injure the reputation or business of a fellow geologist.

SEC. 2. A geologist should not knowingly compete with a fellow geologist for employment by reducing his customary charge.

SEC. 3. A geologist should give credit for work done to those, including his assistants, to whom credit is due.

ARTICLE V. DUTY TO THIS ASSOCIATION

SECTION 1. Every member of the Association should aid in preventing the election to membership of those who lack moral character or the required education and experience.

SEC. 2. A member of this Association who has definite evidence of the violation of the established principles of professional ethics by another should report the facts to the executive committee.

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VOL. 18, NO. 7 (JULY, 1934), PP. 967-968

Memorial

ERIC A. STARKE

Eric A. Starke was born in Prussia, August 10, 1864. He came to the United States when 3 years old, and spent almost his entire life in California, attending the University of California from 1886 to 1890.

He became known in the California oil industry in 1890, and 8 years later developed a new process for treating kerosene. Later he was credited with discoveries in geology which resulted in bringing in the larger part of the Midway field, the Buena Vista Hills, Lost Hills, Kern River Front, and several other southern California fields.

Doctor Starke was chief chemist for the Pacific Coast Oil Company and later for the Standard Oil Company of California. Following his geological work, he became chief geologist and director of exploration for the Standard Oil Company, holding this position for 23 years. For the past 15 years he had been independently engaged as a petroleum engineer in Los Angeles.

He became a member of The American Association of Petroleum Geologists, in 1924. He was also a member of the California Academy of Science and the American Chemical Society.

Doctor Starke died on September 27, 1933, at his home in California, and his death marks the passing of one of the first geologists ever employed by any oil company in California.

He was a man most intensely interested in scientific work, the commercial side being pursued only because of necessity. Many successful geologists obtained their early training under his guidance and inspiration for investigation of geologic facts and their interpretation.

W. S. W. Kew

Los Angeles, California
May 5, 1934

IRA ABRAHAM WILLIAMS

Ira A. Williams was born in Worth County, Iowa, December 24, 1876. His father, David Williams, was born in New York, and his mother, Christene Beyer Williams, was born in Pennsylvania. He graduated from Iowa State College at Ames, Iowa, in 1898, majoring in the science department, and later attended Ohio State University, taking special work in ceramics.

In 1903 he received the degree of Master of Science from Iowa State College, where he had been acting as instructor of geology after completing his course in Ohio State University. He was granted a scholarship to Columbia University, then went for further post-graduate work as a fellow in 1903 and 1904, receiving the degree of Master of Arts. He attended the Harvard Summer School in 1905 and, returning to Iowa State University, became assistant professor of geology and mining until 1906. Following this, he was associate professor of ceramic engineering at Iowa State College until 1913.

Ira Williams in 1913 was asked to establish and take charge of the department of geology in the Oregon State College and was professor of geology

there for 4 years. During this period he was geologist for the Oregon Bureau of Mines and Geology and was the author of many of the published bulletins of the Bureau during that period. He was made professor of ceramics at the University of Washington, at Seattle, and was in charge of this department until 1919, when he returned to Oregon to take the position of geologist with the Oregon Bureau of Mines and Geology.

In 1922 he went into private practice as a consulting geologist. From this time for the remainder of his life, he was very active in work that covered a wide field of geological problems including mining, power site investigation, and petroleum geology.

In addition to his interest in geology, Ira Williams possessed a very sound practical judgment in structural engineering problems. His reputation for accuracy, thoroughness, and reliability on problems of geology involving the construction of dams, placed him in the front rank of consulting geologists of the western states for work of this character. Some of the projects on which he served as consulting geologist were the proposed dams in Deschuttes River for the Columbia Valley Power Company, the Cushman Dam for the City of Tacoma, the Ariel Dam and the Yale dam site for the Northwestern Electric Company, the Youngs Canyon and Mayfield Canyon dams, the Bear Creek Dam for the City of Portland, the Iron Gate dam site on Klamath River, California, and the storage dam site of Rogue River, Oregon. He served as consulting geologist for the United States Army Engineers on problems on Columbia River, Oregon, and as a member of the consulting board for the State Department of Public Works of California.

Ira Williams was the author of many published geological and mining reports for the Iowa Geological Survey, the Oregon Bureau of Mines and Geology, *Mining and Science Press*, and *Brick and Clay Record*. He was also the author of many interesting descriptive articles such as, "The Columbia River Gorge—Its Geological History," "The Oregon Caves," "Tree Casts in Recent Lava," and "The Lava River Tunnel."

His scientific affiliations included: fellow of the American Association for Advancement of Science, fellow of the Geological Society of America, member of the Northwest Science Association, fellow of the American Ceramic Society, member of the Seismological Society of America, fellow of the Iowa Academy of Science, and member of the honorary fraternities Phi Kappa Phi and Sigma Xi. Ira Williams was elected a member of The American Association of Petroleum Geologists in March, 1931.

His outstanding characteristics were honesty, modesty to a fault, loyalty to his friends, pride in excellence of service rendered, and self-discipline. He was a serious-minded, hard-working student with a deep love for all problems of natural science.

He was married in 1910 to Jessie Wood. There are three children: Lloyd Bayard, born in 1913; Rhoda Irene, born in 1916; and David Casimir, born in 1922. Ira Williams passed away on January 21, 1934. He died in his prime, at the height of his career, leaving a vacant place in the hearts of his family and friends which can never be filled. He possessed a vast fund of information of the geology of the Pacific Coast and his death is a very great loss to scientific research in this region.

CLARENCE B. OSBORNE

LOS ANGELES, CALIFORNIA
June 4, 1934

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 7 (JULY, 1934), PP. 969-970

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

W. S. ADKINS, formerly of the Bureau of Economic Geology at Austin, is on the geological staff of the Shell Petroleum Corporation at San Antonio, Texas.

The Oklahoma City Geological Society held a week-end party at Sulphur, Oklahoma, June 16–17. Members and their families attended. CHARLES E. DECKER, of the University of Oklahoma, led a field trip in the vicinity of Sulphur on June 17.

D. BRUCE SEYMOUR, of the Continental Oil Company, Los Angeles, California, met accidental death by falling into the fire pit at a barbecue on May 26.

VERNON E. AUTRY resigned from the Humble Oil and Refining Company, May 1, and is now with Fain and McGaha Oil Corporation, Wichita Falls, Texas. His address is 607 Hamilton Building.

T. R. BANKS, geologist with the Magnolia Petroleum Company, has been transferred from San Antonio to Wichita Falls, Texas.

EDGAR D. KLINGER has accepted a temporary appointment as geologist with the United States Geological Survey to work on the subsurface stratigraphy of north-central Texas. His address is the Federal Building, Coleman, Texas.

D. HAROLD CARDWELL, geologist with the Sun Oil Company, has been transferred from Kilgore to Dallas, Texas.

MILTON HRUBY, formerly of 217 North Park Avenue, Buffalo, New York, is now with the Magnolia Petroleum Company, at San Antonio, Texas.

PERRY OLCOTT, geologist for the Humble Oil and Refining Company, has changed his address from Lake Charles, Louisiana, to Houston, Texas.

GEORGE H. CLARK, geologist for The Texas Company, who for the past two years has been stationed at Livingston, Texas, has been transferred to the district office at San Antonio, and may be addressed at 1701 Alamo National Building.

SYLVAIN PIRSON, who has been teaching during the past year at the Colorado School of Mines, Golden, Colorado, has joined the staff of the Seismograph Service Corporation, at Tulsa, Oklahoma.

LON D. CARTWRIGHT, JR., formerly with Fisher and Lowrie, Houston, Texas, has accepted the position of district geologist for the Skelly Oil Company, Gulf Coast division, and will have charge of geologic work in the coastal districts of Texas and Louisiana, and in the Woodbine district of East Texas. His address is 1305 Esperson Building, Houston.

W. B. SPRAGUE, geologist for The Texas Company, has been transferred from the district office at San Antonio, to the district office at Corsicana, Texas. He may be addressed at 510 State National Bank Building.

The Prussian Geologic Survey has organized a petroleum section (Institut für Erdöl Geologie) under the directorship of DR. ALFRED BENTZ, one of the ranking German petroleum geologists. A branch has been established at Hannover under DR. HAACK, with two geologists as assistants. A second branch in Thuringia is contemplated under the direction of DR. DEUBEL and three geological assistants. A micro-paleontological service under the direction of DR. R. POTONIE is part of the Institut für Erdöl Geologie. A tectonic structure map with the needs of the oil industry in mind is contemplated in coöperation with the Thuringian Geologic Survey. As increased drilling activity has brought special demands on the Prussian Geologic Survey, the new section is organized for closer coöperation with the oil industry in Germany.

At the May and June meetings of the Committee on Grants-in-Aid of the National Research Council, Washington, D.C., the following grants were made in the fields of geology and Geography.

BRADFORD C. ADAMS, Los Angeles, California, "The Foraminifera of a Pliocene Section at Canada de Aliso, Ventura County, California"; GILBERT H. CADY, senior geologist, Illinois State Geological Survey, "The Plant Components in Illinois Coal"; GEORGE B. CRESSEY, professor of geology and geography, Syracuse University, "Geographic Field Work in China"; CHARLES E. DECKER, professor of paleontology, University of Oklahoma, "Studies on Graptolites"; V. C. FINCH, professor of geography, University of Wisconsin, "Preparation of a Series of Isopleth Maps of the United States"; HAROLD L. GEIS, fellow in geology, University of Chicago, "The Taxonomy of the Pennsylvania Ostracods of Illinois"; J. F. LUTZ, assistant professor of soils, North Carolina State College of Agriculture, "Physical and Chemical Properties of Soils Affecting Erosion"; EVANS B. MAYO, instructor in petrography, Cornell University, "The Granites of the Eastern Sierra Nevadas"; WILLIAM F. PROUTY, professor of geology, University of North Carolina, "The Silurian Deposits of Eastern Tennessee"; PARRY REICHE, fellow in geology, University of California, "The Lithology, Structure, and Sequence of the Sur Series of California at its Type Locality"; FRANCIS P. SHEPARD, assistant professor of geology, University of Illinois, "The Submarine Canyons off the California Coast"; C. WARREN THORNTHWAITE, assistant professor of geography, University of Oklahoma, "The Climatic Basis of Forest Distribution in Eastern North America"; SAMUEL WEIDMAN, professor of geology, University of Oklahoma, "Dolomitization, Silicification, and Related Phases of Mineralization Associated with the Zinc-Lead Ore Deposits of the Tri-State District"; E. P. WHEELER, 2nd, Ithaca, New York, "A Study of the Anorthositic Rocks in the Vicinity of Nain, Labrador"; GEORGE W. WHITE, assistant professor of geology, University of New Hampshire, "Mapping of the Wisconsin-Illinoian Glacial Boundary in North and West Central Ohio, by a Study of Soil Minerals."